10-28

William H. Swain | Serial Number 08/579,395 | Prior Art Unit: 2213

Patent and Trademark Office
Commissioner of Patents and Trademarks
Washington, DC 20231

October 28, 1998
Re:
William H. Swain, inventor
Error Correction by Selective Modulation
SN 08/579,395; Filed 12/27/95; Art 2213
Group 2858
703-308-5222, or 305-4900
Primary Examiner: Mr. Ernest F. Karlsen

-1-

#14

Subject:
Reply to the Action of 22 Sept. 1998.

1) Introduction:

This response generally follows the examiner's action of 22 Sept. 1998. William H. Swain 4 Nov. 98 11/13/98

Applicant is pleased that the restriction requirements are withdrawn. This is appreciated. The examiner's substitution of "application" for my "specification" hopefully has no effect.

2) Applicant has kept careful track of the claims and their numbering.

Enclosed Exhibit A shows that all 31 claims were sent to the examiner with applicant's response filed 22 June 98. There are now no other claims. (dated 6-15-98)

Applicant encloses all 31 claims - exactly the same, with this response. I make no other claims.
Paragraph 11.1 thru 11.31; pages C-1 thru C-27.

Enclosed Exhibit B is an updated copy of the Table I sent with my response filed 22 June 98. All 31 claims are listed on one page, together with their Genus and Species, type of claim, amended 6-17-98 note, etc. The left hand column labeled "Examiner" goes back to the old restriction problem, so I have deleted this. The remaining right hand columns under "Applicant", from claim # to the right, are current. Applicant does not now make any other claim.

Applicant requests that the present numbering - claim 1 through claim 31 - be continued. There are no other claims.

11-2-98

Exhibit A

William H. Swain Serial Number 08/579,395 Prior Art Unit: 2213

Filed 22 June 1998

-1a-

June 16, 1998

Patent and Trademark Office
Commissioner of Patents and Trademarks
Washington, DC 20231

Re:
William H. Swain, inventor
Error Correction by Selective Modulation
SN 08/579,395; Filed 12/27/95; Art 2213
Patent Examiner: Mr. Russell M. Kobert
Group 2858
703-308-5222, or 305-4900
Primary Examiner: Josie Ballato

Subject:
Reply to the Action of 8 June 1998.

1) Introduction:

This response generally follows the examiner's action of 8 June 1998.

Applicant accepts that the amendment to the claims included in the reply filed February 17, 1998 have not been entered.

All 31 claims discussed in applicant's reply of 17 Feb 98 are included in this reply. Of these, 26 claims are unchanged, and 5 are amended in comformance with MPEP 714.22 and 37 CFR 1.121(d).

The requested $104 fee is enclosed.

Applicant has long understood that the Examiner has grouped this work into three "inventions", designated by Roman numerals. This and previous responses (Table I on page 2 of 17 Feb 98, in particular) were prepared with this in mind.

Applicant welcomes the Examiner's finding the appearance bona fide in the reply of 17 Feb 98. Considerable thought and time went into it's preparation.

Exhibit B

Table I Updated

-18-

Applicant

Claim	Genus	Species	Type	amended 6-17-98
1	14	Comb	PM	yes
2	14	Comb	PM	no
3	14	Comb	PM	no
4	30	Comb	PM	no
5	30	Comb	PM	no
6	31	Comb	PM	no
7	31	Comb	PM	no
8	14	Comb	AP	no
9	30	Comb	AP	no
10	14	Comb	PM	yes
11	30	Comb	PM	no
12	31	Better	PM	yes
13	31	Better	AP	no
14	Genus 14	General	AP	no
15	14	Better	AP	no
16	14	Comb	AP	no
17	14	Comb	PM	no
18	14	Comb	PM	no
19	14	Comb	PM	no
20	30	Comb	PM	no
21	30	Comb	PM	no
22	31	Comb	PM	no
23	31	Comb	PM	no
24	14	Comb	AP	no
25	30	Comb	AP	no
26	14	Comb	PM	yes
27	30	Comb	PM	no
28	31	Better	PM	yes
29	31	Better	AP	no
30 Genus	(14 Limited to Non-Contact)			no
31 Genus	(14 Limited to Swain)			no

AP = Apparatus
PM = Process of Making

Comb = Combiner Species
Better = Better SNR Species

3.

Claim elements, steps, interconnections, and interrelations are presented - first for the generic claims, and then for the species. Pages 3 thru 79.

Abstract and Traverse of Prior art - 80-90.

I enclose excerpts from relevant drawings and their captions. I also enclose brief descriptions from the 21 Dec. 1995 specification. Moreover, I present a few excerpts from the referenced specification, patent 3,768,011, both drawings and written matter.

A reading of an independent claim begins with a section number. For example:

3.14 is the start of claim 14 reading.

"Quotation" marks are used to show that the marked word is in the claim. Thus:

"essential characteristic" is to be found in the claim being read.

Use is made of annotated excerpts from my application specification of 12-21-95. In defining a required claim element, characteristic, etc., I write claim words in parentheses after application words which here have the same meaning. For example, in section 3.15, paragraph 4, I excerpt from page 4 of the application, saying in part:

changes a great deal more ("substantially altered");

signal input ("physical quantity I"); and

noise ("interference N").

11-2-98

Claim 14

Claim 14 is the generic claim; the most general of apparatus of all. The basic elements, steps and relationships can be illustrated by general statements, and by examples.

Fig. 13 shows a general "sensor".*

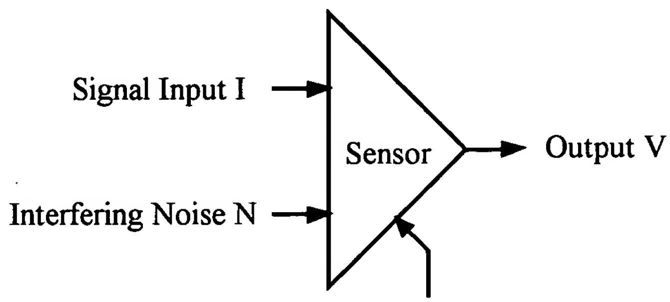


Fig. 13. General representation of a Sensor described in Eq. a) thru Eq. k), pages 13 to 21.

Basically how to build a "sensor", what elements are included, and how they interrelate is detailed in general relationships eq. a) through eq. k) on pages 13 to 21 of the specification.

A brief statement of the general method for building a "sensor" for "measuring" or "controlling" is given on page 1 and annotated as follows:

The method used is usually to find or construct a "sensor" which has a "signal to noise ratio SNR" which changes a lot (is substantially altered) when its "operating parameter (Q)" is "selectively modulated." The "output" (V) of the lower noise sensor is combined with the "output" (V) of the higher noise sensor so that, in the ideal case, the noise "undesired interference

----

* Here, the quotation marks mean that the word SENSOR is used in the claim itself. Therefore, this illuminates an element of claim 14. Similarly for other elements.

10-29-98 C14

N" cancels, but a good signal "physical quantity I" remains. The easier way may be to take part of the output of the higher noise sensor and subtract it from the output of the lower noise sensor. Two sensors can be used, or the operating parameter of one sensor can be modulated (driven) from a higher to lower noise state.

For example, a specific illustration of the core parts of a Swain Meter or Hall ammeter "sensor" are shown in Fig. 1.

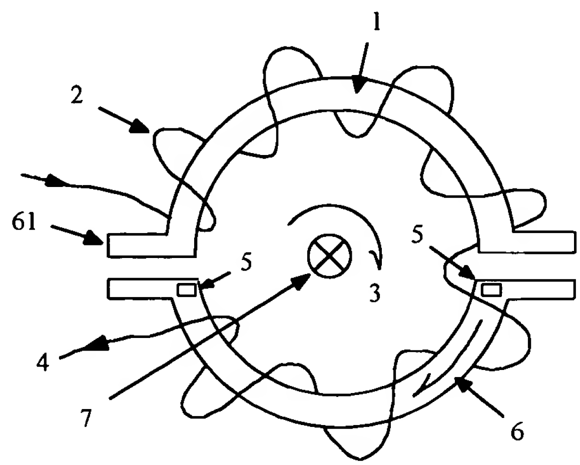


Fig. 1: A clamp-on sensor

Page 2, with annotations, says:

Fig. 1 is a functional diagram of a sensor with a split magnetic core SQ 1 surrounding a conductor carrying a current I 7 to be measured. The core will have a coupling sense winding N_S 2 if it is to be used as a Swain Meter, or alternatively if it is to be used as a Hall type sensor, one or more Hall devices 5 will replace the winding.

In Fig. 1, the core magnetic material is 1. For a Hall ammeter it may have Hall elements 5. For a Swain Meter it will have sense winding N_S 2. An input current 7 ("physical quantity I") creates an input signal magnetic field H_i 3 which is coupled to and offsets the magnetic state of core 1 in the desired manner so that the "sensor" can "measure" or "control" the "physical (input) quantity I".

10-29-98 C14

The magnetic state core 1 is also offset in an "undesired" way by magnetic noise "interference N". There are at least 2 types. H_μ and H_n.

Uniform field H_μ is generally from the Earth Magnetic field H_e. It is shown in Fig. 2.

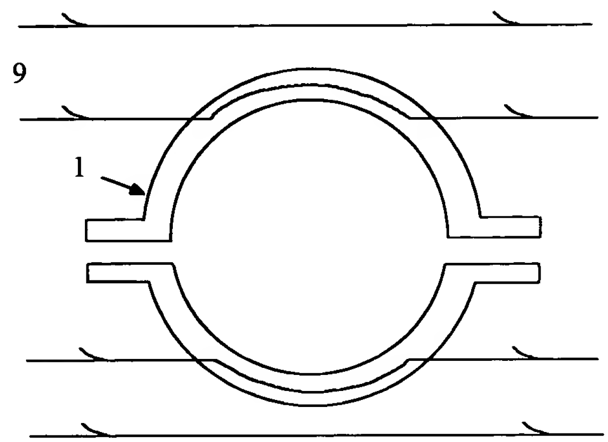


Fig. 2: Uniform magnetic field (H_u) 9 of the earth H_e acting on the core.

Page 2 says:

Fig. 2 illustrates interference from the uniform magnetic field H_μ due to a very remote and large field such as that of the earth, H_e.

Non-uniform field Hn is generally from a nearby magnetized structure - pipe, rebar, etc. It is shown in Fig. 3.

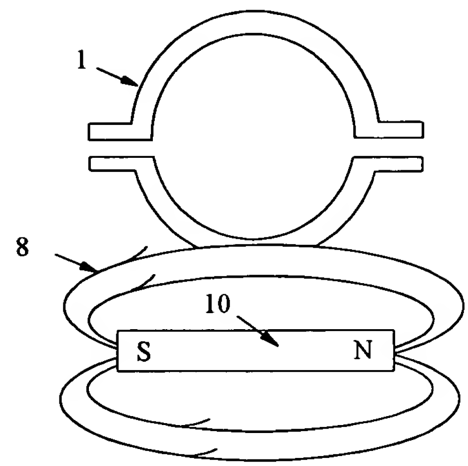


Fig. 3: A non-uniform magnetic field (H_n) 8 from a magnet acting on the core

Page 2 says:

Fig. 3 illustrates interference from the non-uniform magnetic field H_n due to a magnet near the sensor.

A specific example for illustrating "SNR" in a "sensor" is shown in Fig. 5. The caption shows relationships "δV/δI" is change in "output V" in "response to" a change in "physical quantity I", i.e., an signal input current I.

The title on specification page 2 for Fig. 5 points to this showing of the "essential characteristic". It says:

Fig. 5 is a graph illustrating the "essential characteristic" in terms of signal to noise ratio SNR for 5" diameter aperture clip #88.

10-29-98 C14

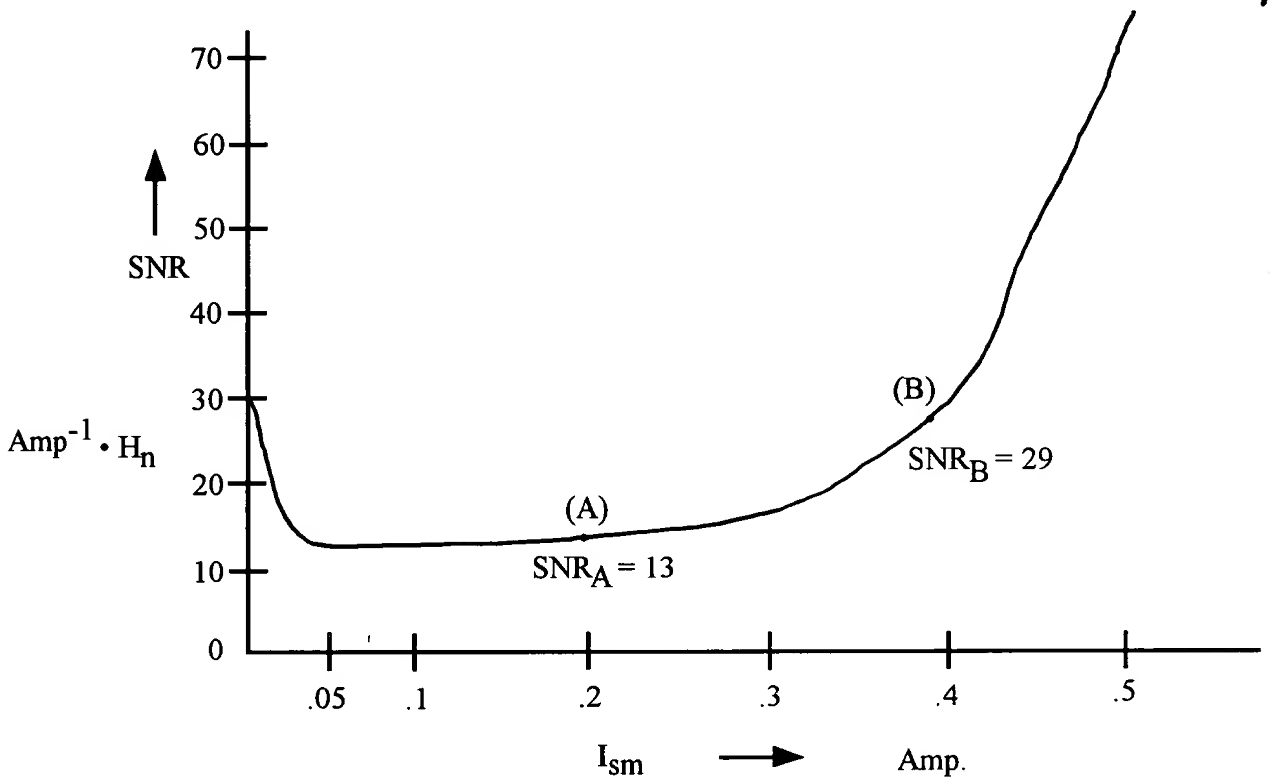


Figure 5
Signal to Noise Ratio (SNR) for Non-Uniform Field H_n
vs.
Operating Parameter I_{sm}
for
5" dia. aperture clip #88 in SN 2336

output input

$$SNR \equiv \frac{\delta V / \delta I}{\delta V / \delta N} \Big\} \frac{\text{output}}{\text{noise}}$$

$$= \frac{\text{gain}}{\text{gain} \cdot \frac{\delta \acute{O}}{\delta N}} \longleftarrow \frac{Z}{g} = \text{equivalent input offset I}$$

per
unit non-uniform field H_n

Also the caption of Fig. 5 shows relationship "δV/δN" is change in "output V" in response to a change in "undesired interference N" i.e., non-uniform field H_n.

10-29-98

C14

Fig. 5 caption further states: "Signal to noise ratio" "SNR" is the ratio of the above terms.

The graph on Fig. 5 shows that the 5" clip "sensor" #88 used here as an illustrative example had a "SNR" which was "substantially altered" (SNR changes from a minimum of 13 to more than 29) by a change in "operating parameter Q" (here Q is I_{sm}) by "selective modulation" from I_{sm} = .2 Amp to I_{sm} = .4 Amp or more.

This illustrates that this "sensor" has the "essential characteristic".

The "essential characteristic" is demonstrated in the illustrative example Fig. 5. The specification states on page 13: (Box added):

The "essential characteristic" necessary for good error correction by "selective modulation" can be measured and presented in several ways, but that shown in Fig. 5 - the plot of "SNR" vs. "operating parameter" is now considered the most basic. A good (essential) characteristic such as that in Fig. 5 has a substantial change in SNR - two to one or more - over a practical range of the condition of the operating parameter. It is not necessary that the gain g be nearly constant. Good correction can be had when the gain g changes 40% as the "operating parameter Q" is driven (selectively modulated) from one condition to another.

The basis is the <u>Discovery</u> given on page 11. It says:

DISCOVERY

The inventor discovered that the output V of many Swain Meter clamps was a lot less sensitive (1/1 to 1/3 in some sensors) to a change in the intensity of a non-uniform magnetic field H_n when the magnitude of an operating parameter I_{sm} was doubled or tripled. And the sensitivity (gain) to a change in signal input current I stayed constant to within a few percent.

10-29-98 C14

An illustrative example of "means enabling" is discussed on page 32. Excerpts follow:

Fig 9 starts where the cover drawing (Fig. 2) in U.S. Patent 3,768,011 left off. A special inverter is connected in series with the winding on the core of the non-contact sensor....

--- later ---

In Fig. 9 the special inverter 15 operating at frequency f_o is series connected with the sensor's coupling sense winding 2 and the parallel combination of capacitor 16 and resistor 17. Input current 7 influences the magnetic material in the core 1, and so also does the magnet 10. So the average current 4 in the loop produces a voltage V_c across capacitor 16 and resistor 17 which is proportional to the input current 7, and also proportional to the effect of noise magnet 10 and its non-uniform field 8. In this implementation, the means driving the operating parameter I_{sm} (12) from 0.2 to 0.4 Amp is an electronic switch 18.

Interconnections joining elements are diagrammed on Fig. 9.

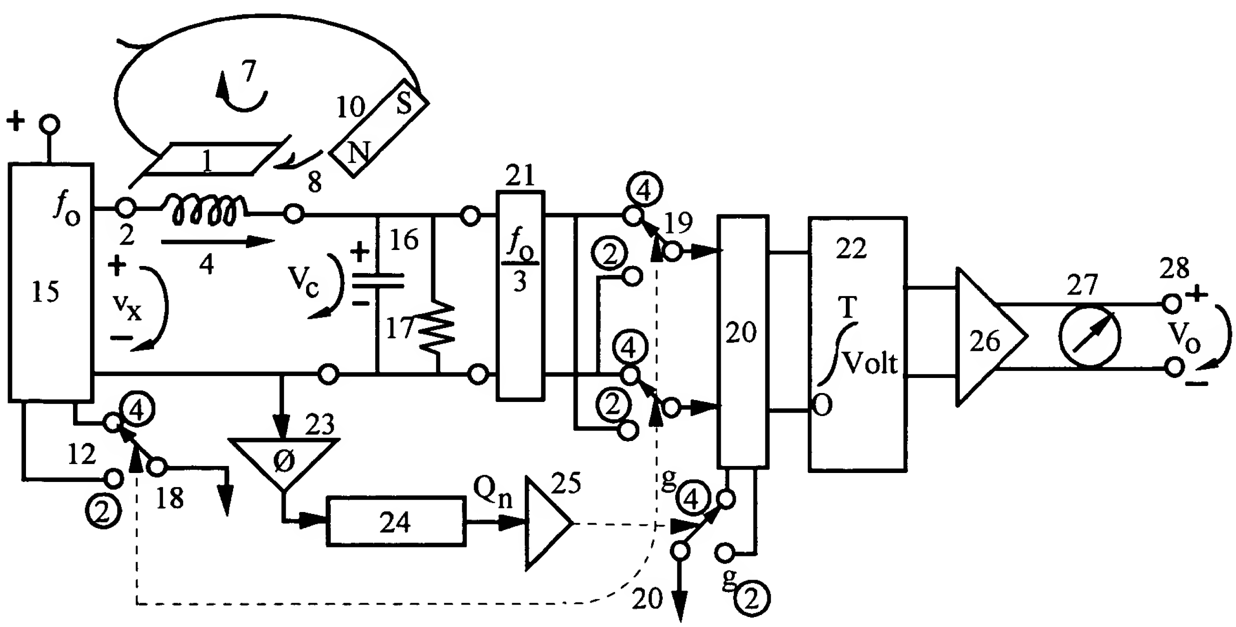


Fig. 9: A switching implementation of the mathematical relationship shown in Eq. i).

10-29-98 C14

Fig. 9 is a functional diagram of a switching implementation of the method as stated in a mathematical relationship.

The timing of the steps in the functioning of Fig. 9 is shown in Fig. 10. This timing is discussed in specification pages 32 to 35.

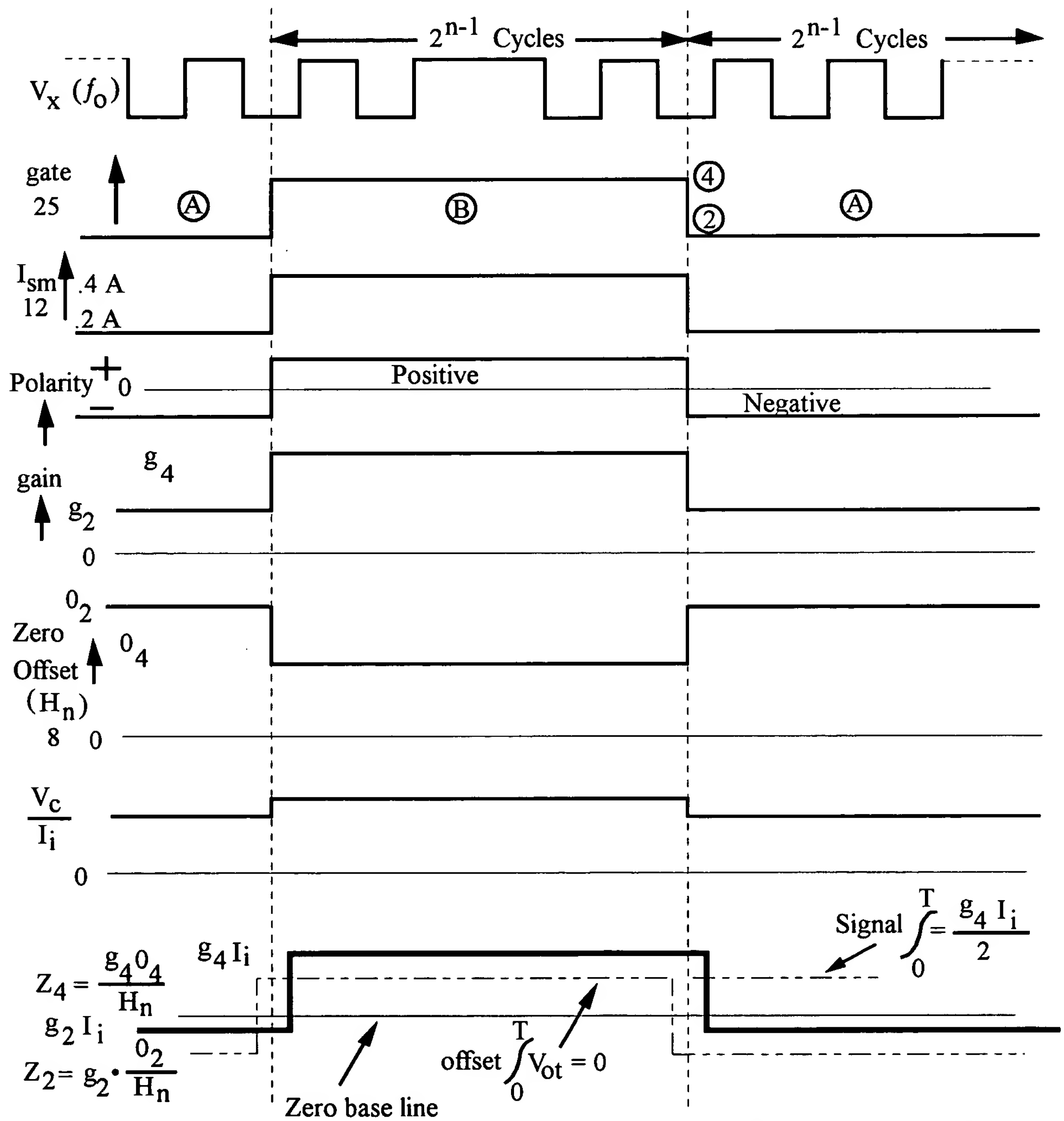


Fig. 10: Voltages in Fig. 9 shown as they change from time interval Ⓐ to time interval Ⓑ.

10-29-98

C 14

The illustrative example Fig 9 includes “means enabling” the “sensor” to in some designs “function” “independently”. A meter can be connected to V_c shown across capacitor 16.

In other designs to “function” as “part of a machine” more Fig. 9 elements may be needed. The output V_0 28 derived from amplifier 26 will likely interface well with a “machine”.

Hall devices are next used to illustrate the elements in claim 14 instead of the Swain Meter device emphasized above.

Hall elements 5 are shown in clamp-on sensor Fig. 1 which is the second drawing at the start of this claim 14 element description.

Page 38, 39... (annotated) says:

Hall Devices

Introduction

We have seen clamp-on DC ammeters which incorporate Hall devices (‘sensors”). In a Hall device, the output voltage is the product of a bias current and a flux density-all 3 being orthogonal in a silicon crystal. We have observed that Hall type instruments (“machines”) made by F.W. Bell of Orlando, Florida, and by LEM HEME of England and Milwaukee, Wisconsin have zero offset (“error”) which changes as the clip moves in the uniform field H_u of the earth (“undesired interference N”). We have also measured the LEM model PR-20 near a magnet (“undesired interference N”) and have found that it's zero offset (“error”) is changed by a non-uniform magnetic field H_n.

It is desired to correct Hall devices for zero offset error due to:

a) Non-uniform field of nearby magnet (H_n).

b) Uniform field (H_u), like that of the earth (H_e).

10-29-98 C14

First Calibration

For a first calibration, very strong Órthogonal magnets (“selectively”) “modulated” the gain. In the experiment, the modulated parameter (“operating parameter Q”) was the strength of a magnetic field orthogonal to the signal (“physical quantity I”) field. This saturated the signal path and so modulated the reluctance of the core carrying signal flux to the hall devices. The results appear below.

Table III

	No magnet present	Órthogonal magnet present	Ratio of gain or error
a) Gain (g) for input current I_i:	$\frac{100\ mV}{A}$	130 or 150 mV/A	0.77
b) Earth field (H_e) error:	43 mA* ↑	↖ 1.58* A	0.027
c) H_n error due to "GE" radio speaker (as used with our ¾" & 5" clip tests)	(*these are equivalent input currents, Ó)		
	$\frac{130*\ mA}{\text{"GE"}}$	$\frac{9.8*\ Amp}{\text{"GE"}}$	0.013

In table III above the ratio of errors due to H_e (Fig. 2) is .027 to one, but the gain g is relatively stable at .77 to one. So the “SNR’s” differ by 28 to one with and without “selective modulation of the operating parameter.” For H_n (Fig. 3) the “SNR” ratio is 59 to one.

It is clear that this LEM model PR-20 “machine” has a “sensor” with the “essential characteristic” “that the signal to noise ratio SNR” is “substantially altered” by “selective modulation of an operating parameter Q.”

A general method for building an “improved sensor” as depicted in Fig. 13 above is given in pages 14 to 16 to 21. The terms such as “SNR” are broadly defined - the same for Hall or Swain or other type sensors.

10-29-98   C14

Page 4 (annotated) introduces the reluctance parameter:

Second Calibration

We further calibrated the LEM model PR-20. The ("selectively") "modulated" ("operating") "parameter" was the air gap of the core. This changed the reluctance of the core for signal ("physical quantity I") flux. The added reluctance of the overall core, especially near the nose where the several layers of thin plastic bubble were placed, provided "selective modulation." The gap was probably 2 to 5 thousandths of an inch. The results are given in Table IV.

Table IV

	No gap	With gap	Ratio of gain or error
Gain (g) for input current I_i	$\frac{100.55\ mV_O}{Amp.\ in}$	$\frac{100.35\ mV_O}{Amp.\ in}$	0.998
Earth Field (H_e) error	$\frac{3.8\ mV_O}{Earth\ circle}$	$\frac{5.7\ mV_O}{Earth\ circle}$	0.67
"GE" Magnet (H_n) error	$\frac{11.5\ mV_O}{"GE"}$	$\frac{34.6\ mV_O}{"GE"}$	0.33

Again the gain is stable but the zero offset error due to H_e (Fig. 2) changed by .67 to one. Error due to H_n (Fig. 3) changed .33 to one. So the SNR's changed 1 ½ or 3 to one - showing that this LEM PR 20 has the "essential characteristic" when core reluctance is the "operating parameter Q" "selectively modulated."

Page 3 introduces reluctane modulator Fig. 12 which further specifies elements and their relationship for a Hall type "sensor" or "machine" in claim 14.

Fig. 12 illustrates a proposed core structure and selective modulation means for a Hall type clamp-on ammeter.

10-29-98 C14

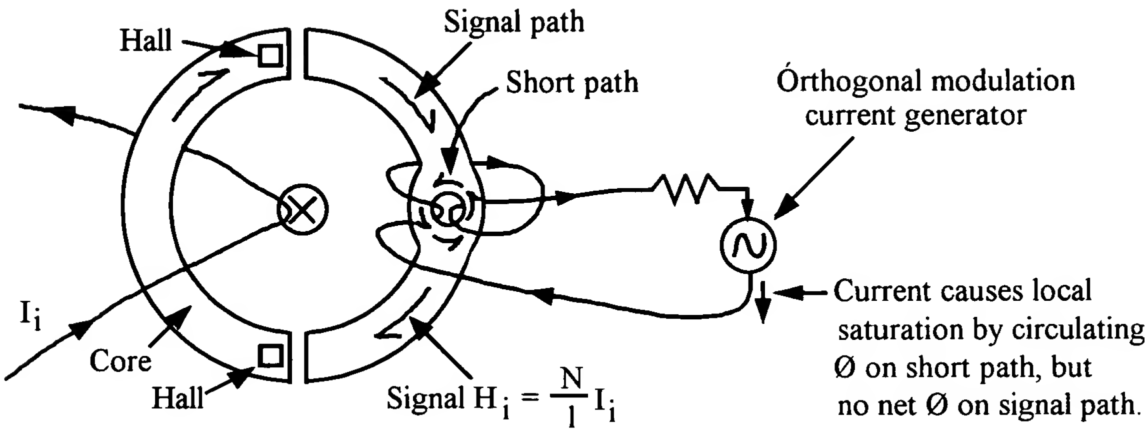


Fig. 12: Proposed core structure and magnetic reluctance selective modulation means for a Hall type clamp-on DC ammeter.

The core 1 in Fig. 12 resembles that shown above in Fig. 1. Here I_i is the "physical quantity I" shown as 7 in Fig. 1. Hall elements are 5 in Fig. 1.

10-29-98 C14 //

3. 30

Claim 30 is a generic claim for "non-contact" "current sensor" apparatus. The elements and inter-relationships for claim 30 are put forth in several ways in diverse parts of the specification. The following illustrative examples are selected for simplicity and brevity. They are ordered much as in claim 30.

Fig. 9 is a functional diagram of a switching implementation of the method as stated in a mathematical relationship.

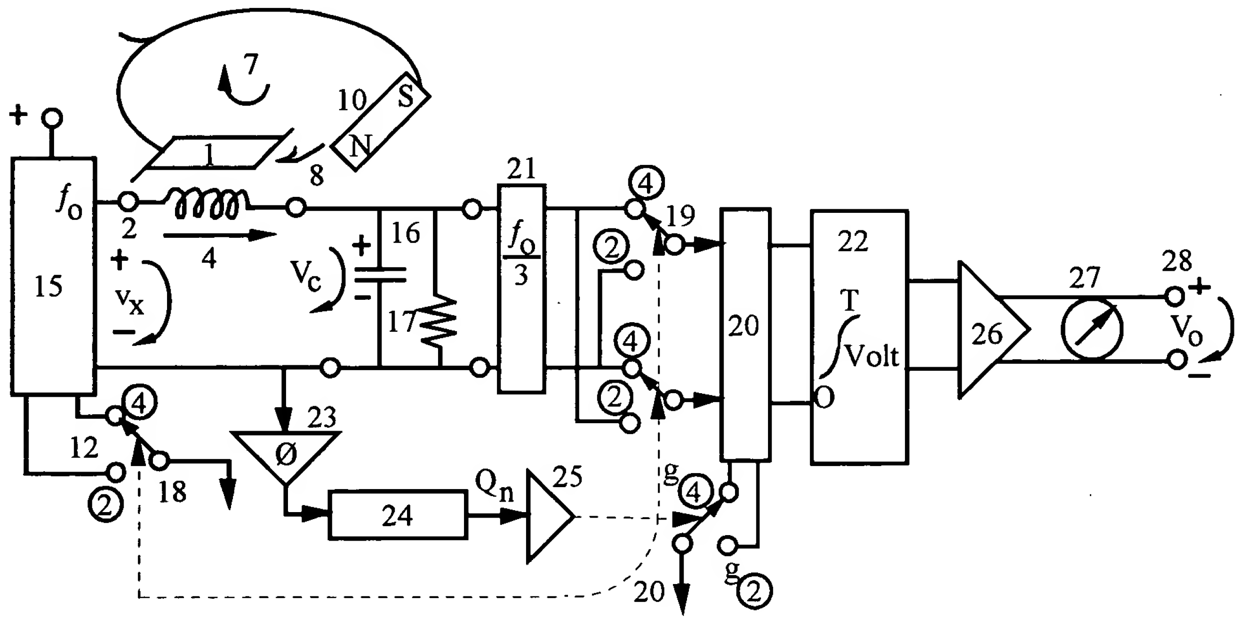


Fig. 9: A switching implementation of the mathematical relationship shown in Eq. i).

Elements detailed on page 32 include:

Core 1,

Sense winding N_S 2,

Average current I_S 4,

Low input impedance means capacitor 16 and resistor 17 for converting average current I_S 4 to an output voltage V_C across capacitor 16, and

10-30-98

A special inverter 15 connected to a switch 18. This modulates operating parameter "Q", the magnitude of I_{sm} 12 from 0.2 (point A) to 0.4 (point B). Reference Fig. 2 shows R_{sm}, the magnitude of which determines the magnitude of I_{sm} 12.

Also in Fig. 9:

Sensor "output V" is the voltage V_c across capacitor 16.
"Signal current I" is shown as 7.

"Magnetic field noise N" is magnet coupled to core 1 so as to influence it's magnetic condition.

"Magnetic field noise N" is also represented physically in Fig. 2 as uniform Earth field H_e 9 coupled to core 1.

Fig. 1 is a functional diagram of a sensor with a split magnetic core SQ 1 surrounding a conductor carrying a current I 7 to be measured. The core 1 will have a coupling sense winding N_s 2 if it is to be used as a Swain Meter, or alternatively if it is to be used as a Hall type sensor, one or more Hall devices 5 will replace the winding 2.

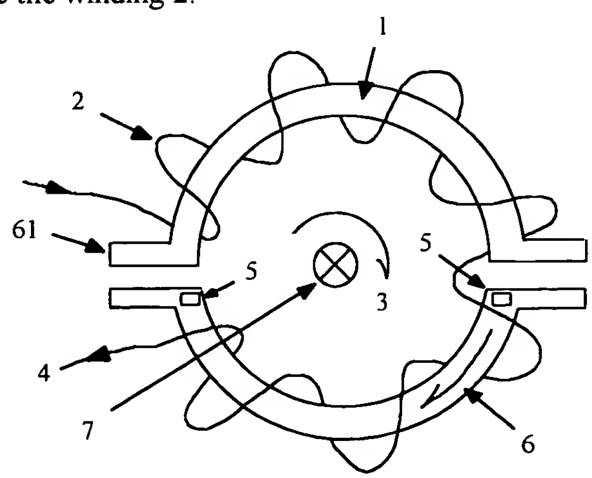


Fig. 1: A clamp-on sensor

In Figure 1 the "signal current I" is shown as conductor 7 carrying a current in the aperture of core 1 having sense winding N_S 2 having average current I_S 2.

Non-uniform local "noise N" magnet 10 field 8 is shown in Fig. 3, likewise coupled to core 1 of Fig. 1. Page 2 describes Fig. 3:

Fig. 3 illustrates interference from the non-uniform "magnetic field" Hn due to a magnet near the "sensor."

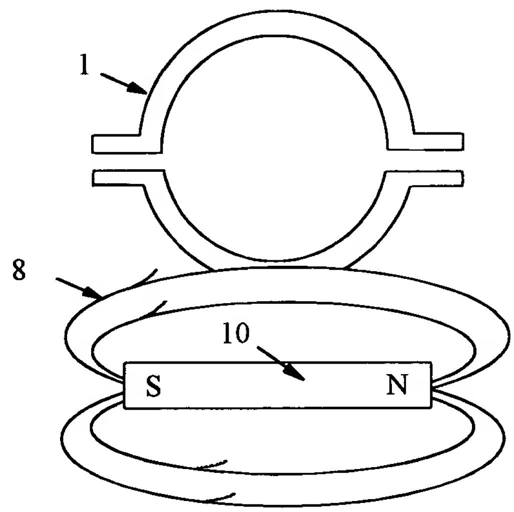


Fig. 3: A non-uniform "magnetic field" (H_n) 8 from a magnet acting on the core (1).

A sensor is more accurate if SNR is high because it is more able to reject zero offset error due to "interfering magnetic noise N." Page 2 shows the relationship:

Fig. 5 is a graph illustrating the "essential characteristic" in terms of "signal to noise ratio SNR" for 5" diameter aperture clip #88.

10-30-98

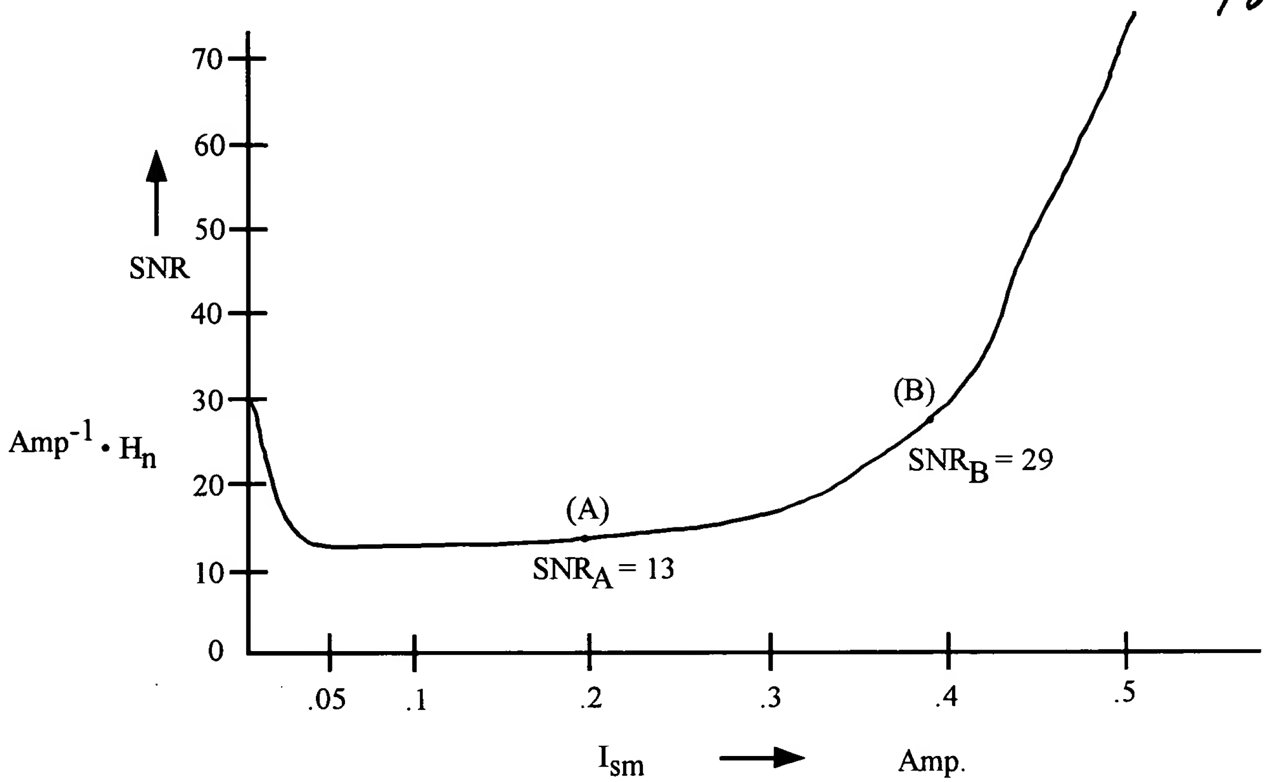


Figure 5
Signal to Noise Ratio (SNR) for Non-Uniform Field H_n
vs.
Operating Parameter I_{sm}
for
5" dia. aperture clip #88 in SN 2336

$$\mathrm{SNR} \equiv \frac{\overset{\text{output}}{\delta V} \big/ \overset{\text{input}}{\delta I}}{\delta V \big/ \delta N} \Big\} \ \frac{\text{output}}{\text{noise}}$$

$$= \frac{\text{gain}}{\text{gain} \bullet \dfrac{\delta \acute{O}}{\delta N}} \leftarrow \frac{Z}{g} = \text{equivalent input offset I per unit non-uniform field } H_n$$

The relationship "SNR" is shown in Fig. 5. In this representation the SNR of point B on the graph is double that at point A. This says that the SNR is "substantially altered." The magnitude of the operating parameter Q (I_{sm} in Swain Meters) is the only thing that changed. It is the same sensor with the same construction using the same material at both A and B.

This Fig. 5 is an illustration of the "Essential Characteristic" - namely - SNR changes a lot (is "substantially altered") when an operating parameter Q is changed.

For us, there are at least two types of sensors. As a "Non-contact current sensor" I also used a LEM model PR-20 to show that a Hall device had the "Essential Characteristic". Catalog sheet exhibit L enclosed describes the physical and technical details and gives a picture. Letter exhibit M enclosed gives their address and source for more data.

"Output V" and "signal current I" are stated in exhibit L. "Magnetic field noise N" data was not seen in exhibit L so I conducted tests. Results are given in the specification, especially in tables III and IV on pages 39 and 40.

"Selective modulation of an operating parameter" was achieved, in one experiment, by a strong magnetic field perpendicular to the main axes of the clip (orthogonal magnet, table III). In another experiment, I put an air gap in the core (gap, table IV).

In each experiment the Hall "non-contact current sensor" was found to have the "Essential Characteristic" that the SNR was "substantially altered" by a change in an operating parameter.

When "Operating parameter Q" was an orthogonal magnet the SNR changed by over 30 to one for either Earth magnetic field (H_e) noise or GE speaker magnet (H_n) noise; yet the gain changed less than 2 to one.

When "Operating parameter Q" was a gapped core the effect was sufficient but less drastic. The SNR was changed by 1.5 to one or more, but the gain changed less than 0.2%.

10-30-98 30

A gapped core “Operating parameter Q” may be more conveniently implemented by increasing the reluctance of the core with an orthogonal modulation current generator. Page 3 introduces Fig. 12.

Fig. 12 illustrates a proposed core structure and selective modulation means for a Hall type clamp-on ammeter.

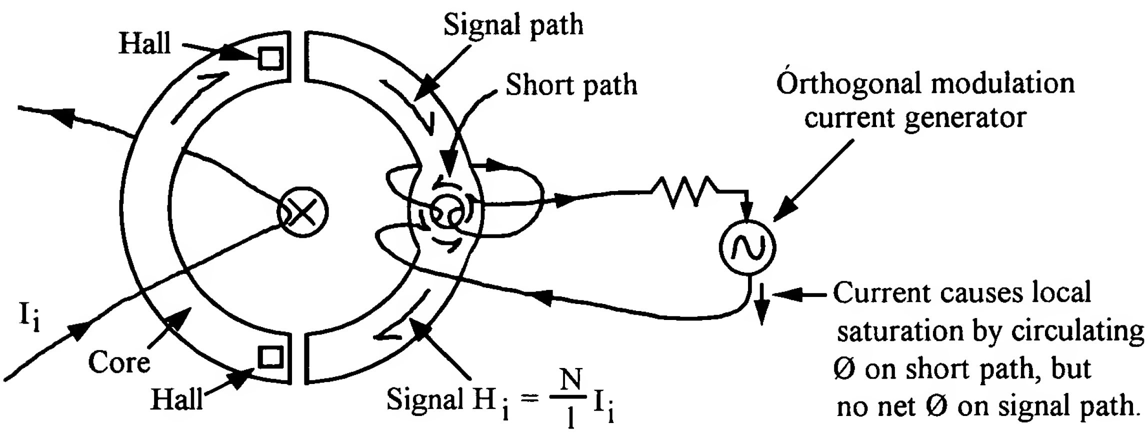


Fig. 12: Proposed core structure and magnetic reluctance selective modulation means for a Hall type clamp-on DC ammeter.

Several examples of “means enabling” are shown in the specification. An illustration is Fig. 9. It’s detailed operation is shown especially on pages 32 and 33. The timing inter-relationship is shown in Fig. 10, and described on pages 34 and 35.

Another example of “means enabling” is Fig. 11. It is described on pages 37 and 38.

The “machine” output is meter 27 and output terminals 28.

10-30-98

Exhibit M

LEM

-208-

September 21, 1995

William H. Swain
William H. Swain Company
239 Field End Street
Sarasota, FL 34240-9703

Dear Mr. Swain,

Thank you for your recent request for information on LEM Current Probes.

Enclosed for your reference is a brochure detailing information about the LEM PR Series hand-held current probes.

Our PR Series Current Probes allow easy retrieval of current readings accurate to 1% of indicated value and deliver resolution from +/- 1 mA to +/- 100 mA. Additionally, LEM probes comply with IEC 1010/UL 3111 safety standards.

We appreciate your interest in LEM current probes. If you have any questions or require additional information, please contact us at 1-800-236-5366.

11-4-98

LEM U.S.A., INC.

6643 WEST MILL ROAD
MILWAUKEE, WI 53218

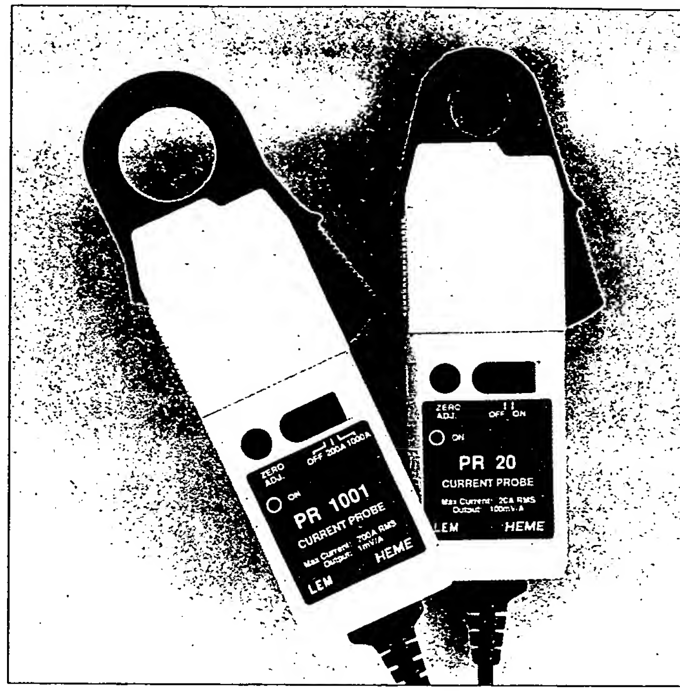
TEL: 414/ 353 0711
FAX: 414/ 353 0733

Exhibit L

LEM

- 20a -

The probes are powerful tools for multimeter and oscilloscope users, providing new solutions to current measurement. With the clip-on design, measurement is fast and convenient since there is no need to break into the circuit.



PRODUCT FEATURES INCLUDE

- **Currents from 5mA to 1000A Peak**
- **Frequency ranges up to 100kHz**
- **1% accuracy**
- **Instantaneous voltage outputs of 1mV/A, 10mV/A and 100mV/A**
- **Compact and self-contained**

SPECIFICATIONS

	PR30	PR20	PR200		PR1001	
Parameter	Oscilloscope Probe	Multimeter/Recorder Probes				
CURRENT RANGES	AC 20A RMS DC 30A	AC 20A RMS DC 30A	AC 20A RMS DC 30A	AC 200A RMS DC 300A	AC 200A RMS DC 300A	AC 1000A Pk DC 1000A
RESOLUTION	± 1mA	±1mA	±10mA	±100mA	±100mA	±100mA
OUTPUT SENSITIVITY	100mV/A	100mV/A	10mV/A	1mV/A	1mV/A	1mV/A
ACCURACY (of rdg)	±1% ±2mA	±1% ±2mA	±1% ±0.03A	±1% ±0.3A	±1% ±0.5A	±1% ±0.5A
FREQUENCY RANGE	DC to 100kHz	DC to 20kHz	DC to 10kHz		DC to 10kHz	
GAIN VARIATION	±0.01% rdg/°C	±0.01% rdg/°C	±0.1% rdg/°C		±0.1% rdg/°C	
RESPONSE TIME	< 1 μsec	< 1 μsec	< 10 μsec		< 10 μsec	
di / dt FOLLOWING	> 20 A/μsec	> 20 A/μsec	> 20 A/μsec		> 20 A/μsec	
DIELECTRIC STRENGTH	3.7kV rms 50Hz 1 min					
OUTPUT CONNECTIONS	BNC plug	4mm safety plugs				
CABLE LENGTH	2 m	1.5 m				
LOAD IMPEDANCE	> 100kΩ	> 10kΩ				
OPERATING TEMPERATURE	11-4-98 0°C to +50°C					
OPERATING HUMIDITY	15% to 85% RH (non-condensing)					

GENERAL DATA

Dimensions
L x W x D
PR20, 30, 200
183 x 71 x 31mm
PR1001
196 x 71 x 31mm

Weight
250-300g

Max. Conductor Size
PR20, 30, 200
19mm diameter 3/4"
PR1001
31mm diameter 1.2"

Power Supply
9V Alkaline PP3

Battery Life
PR20, 30
approx. 30 hours
PR200, 1001
approx. 50 hours

Safety

PR500 and PR1000 Current Probes
For current measurement on large conductors

The PR500 and PR1000 have been developed for use with digital multimeters and oscilloscopes for the measurement and analysis of current in large conductors. Using advanced Hall Effect technology the probes will accurately measure DC and AC current up to 3kHz. The current ranges of the units are 1000 Amps DC or AC peak for PR1000 and 500 Amps DC or AC peak for the PR500.

Features include:

- AC and DC capability
- Conductor size up to: 48mm cicular
  22mm x 60mm rectangular section
- 1% Accuracy ± 1A — 1,35"x 2,36"
- Overload Capacity: 1000%
- Frequency Range: DC to 3kHz
- Battery Life: 50 hours continuous operation
- Output: 1mV/Amp
- Weight: 620 grammes
- Operating Temp: 0°C to +50°C.
- Cable Length: 2 Metres
- Dimensions: 260mm x 90mm x 70mm

Other Products

LEM HEME produce a comprehensive family of products for the non-intrusive measurement of electrical parameters.This includes clip-on ammeters, power meters, probes and transducers.

The standard range of clip-on ammeters from LEM HEME offer measuring capabilities up to 2000 Amps with an accuracy of 1% and feature DC, AC and true RMS current measurement for complex waveforms.

The Analyst range takes portable power measurement instrumentation into new territory. The microprocessor-controlled instruments incorporate multimeter and oscilloscope functions in their impressive array of measurement options. Accessories include an interface and software for data logging of measured parameters to a personal computer and a three-phase adaptor for applications where the neutral conductor is inaccessible.

Customised versions of instruments and probes are available. Further details, on the above products, can be obtained from LEM subsidiaries and authorised distributors worldwide.

LEM U.S.A., Inc.

Mill Run Business Center
6643 W. Mill Rd. • Milwaukee, WI 53218
(414) 353-0711 FAX (414) 353-0733

LEM HEME LIMITED 1 Penketh Place, West Pimbo, Skelmersdale, Lancashire, United Kingdom. WN8 9QX

Telephone 01695 720535 Telex 629792 HEME G Fax 01695 50279
International: Telephone +44 1695 720535 Fax +44 1695 50279

LEM Subsidiaries:

Claim 31 is a generic claim for apparatus similar to Swain Meters. Page 1 defines basic elements and relationships.

(a) Title: Error Correction by "Selective Modulation"

(c) Reference: U.S. Pat 3,768,011 granted to William H. Swain

(d) Summary. (annotated)

This invention relates to "sensors" and/or "implements" for "measurement or control."

The object of the invention is to improve accuracy by reducing error in the "sensors" "output" ("V") when in the presence of an "interfering" "noise" source ("N").

The method used is usually to find or construct a "sensor" which has a "signal to noise ratio SNR" which changes a lot ("substantially altered") when its "operating parameter" ("I_{sm}") is "selectively modulated."

"Sensor" elements are further illustrated in the example in Fig. 1. It's title (annotated) on page 2 says:

Fig. 1 is a functional diagram of a sensor with a split magnetic core SQ (1) surrounding a conductor carrying a "current" I (7) to be measured. The core will have a coupling sense winding N_S (2) if it is to be used as a Swain Meter, or alternatively if it is to be used as a Hall type sensor, one or more Hall devices (5) will replace the winding.

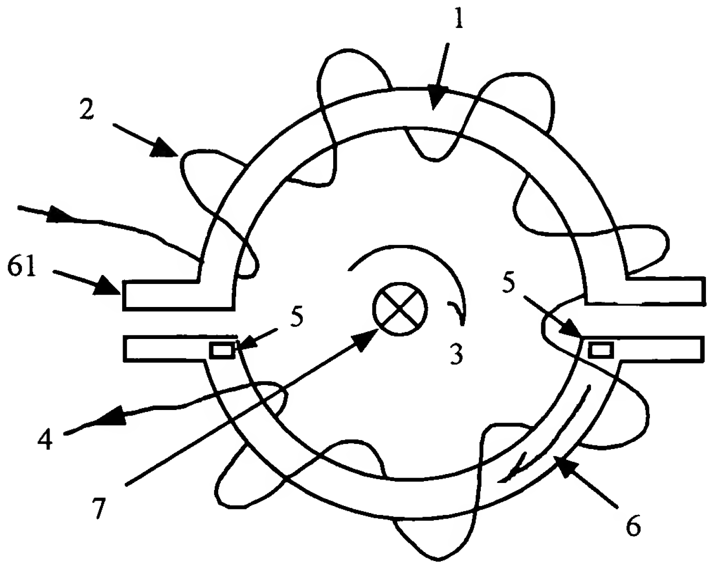


Fig. 1: A clamp-on sensor

Pages 8 and 9 further define elements in Fig. 1.

Page 2 relates the elements shown in Fig. 5, saying:

Fig. 5 is a graph illustrating the "essential characteristic" in terms of signal to noise ratio SNR for 5" diameter aperture clip #88.

-23-

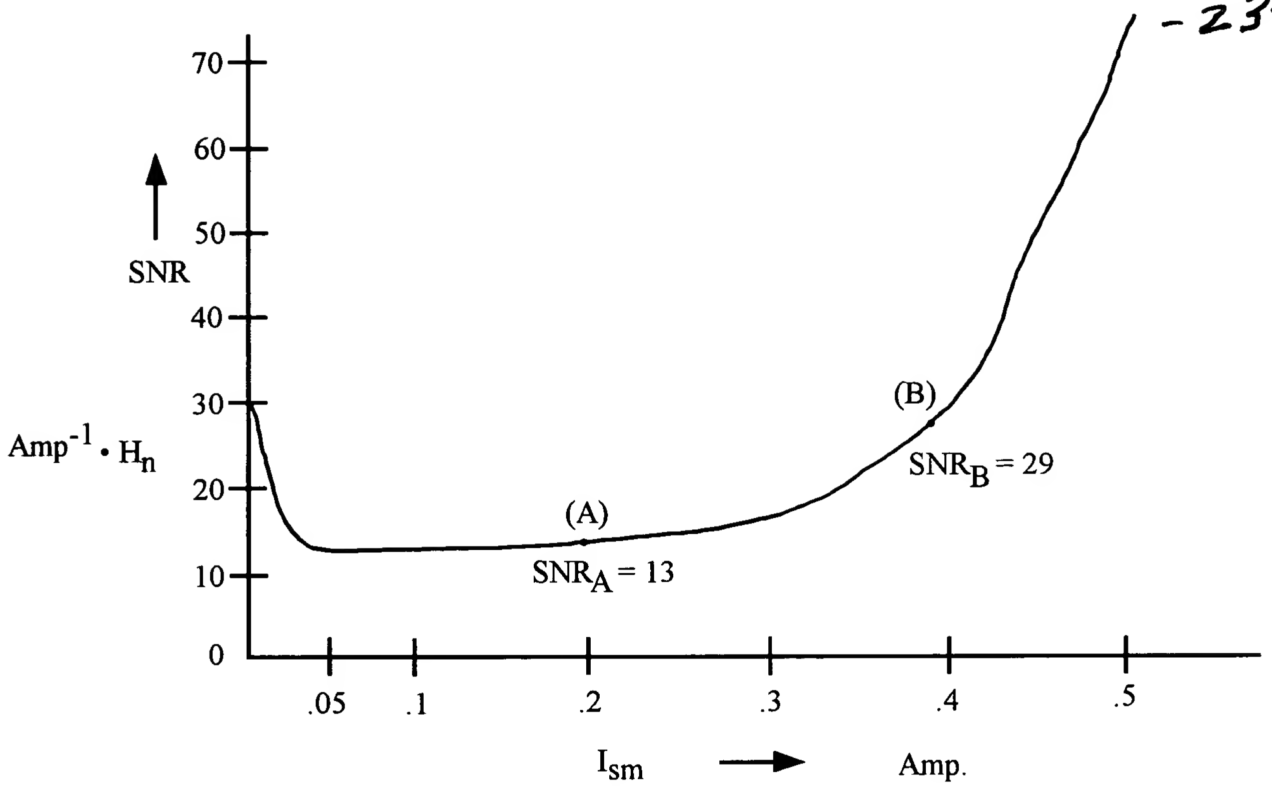


Figure 5
Signal to Noise Ratio (SNR) for Non-Uniform Field H_n
vs.
Operating Parameter I_{sm}
for
5" dia. aperture clip #88 in SN 2336

$$SNR \equiv \frac{\overset{\text{output}}{\delta V} / \overset{\text{input}}{\delta I}}{\delta V / \delta N} \Big\} \frac{\text{output}}{\text{noise}}$$

$$= \frac{\text{gain}}{\text{gain} \cdot \frac{\delta \acute{O}}{\delta N}} \longleftarrow \frac{Z}{g} = \text{equivalent input offset I per unit non-uniform field } H_n$$

In claim 31, "direct current signal input I" is flowing in Fig. 1 in element 7. The above caption for Fig. 5 relates this same current change (input δI) to a change in sensor "output V" as (output δV) as part of the "SNR" definition. The change in (noise δN) is due to moving "interfering magnetic field noise N" shown as H_n in Fig. 3 of which page 2 says:

10-30-98 3r

Fig. 3 illustrates "interference" from the non-uniform "magnetic field" H_n due to a magnet near the sensor.

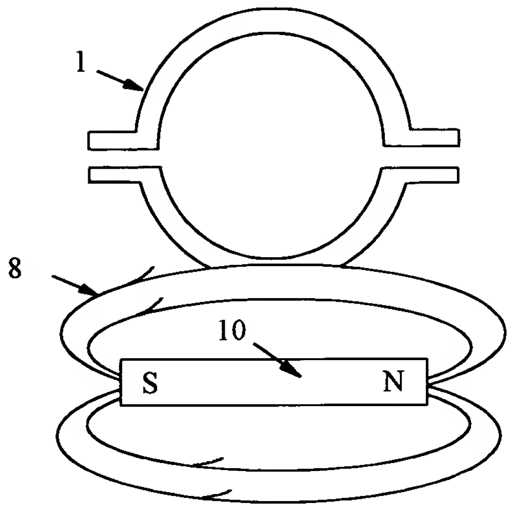


Fig. 3: A non-uniform "magnetic field" (H_n) 8 from a magnet acting on the core (1).

"Means enabling"... "function"... "machine, or independently" are illustrated with interconnections in the example Fig. 9, of which page 3 says:

Fig. 9 is a functional diagram of a switching implementation ("means enabling") of the method as stated in a mathematical relationship.

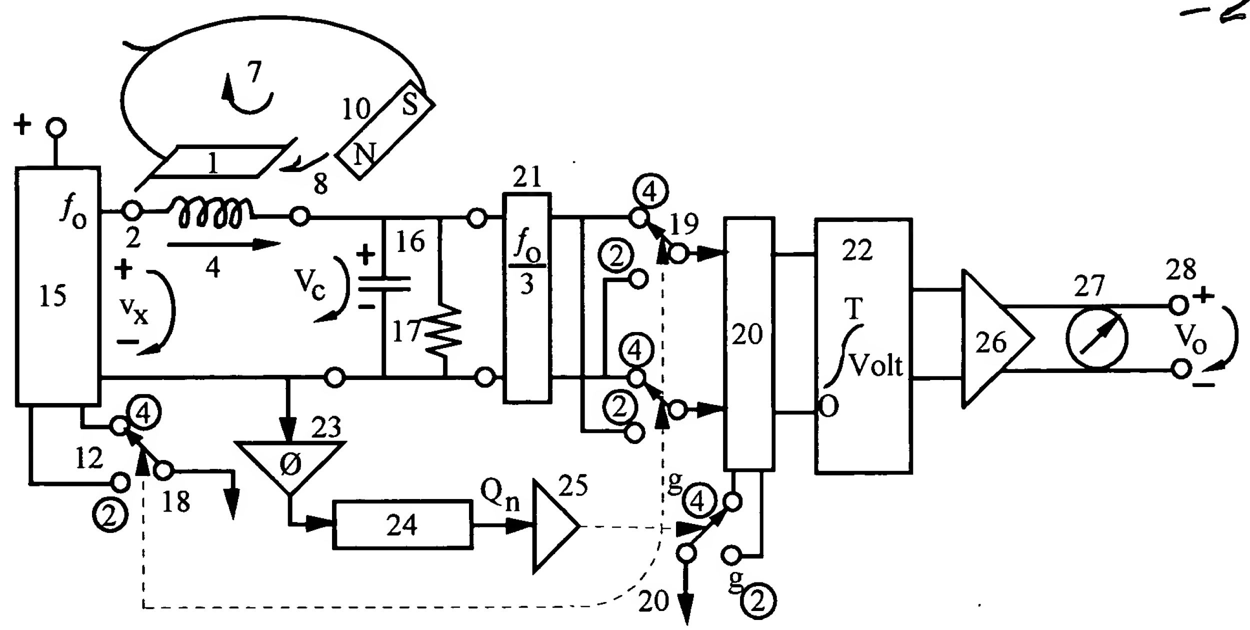


Fig. 9: A switching implementation of the mathematical relationship shown in Eq. i).

The elements in Fig. 9 such as inverter 15 are detailed on page 32. Timing steps are shown in Fig. 10. Briefly:

In Fig. 9, the "sensor" core 1 is influenced by "direct current signal input I" 7, and also by "interfering magnetic field noise" 8 from magnet 10. "Sensor" "output V" is V_c across capacitor 16.

In this example "machine" outputs V_o 28 and meter 27 are reached more simply in the "better SNR" species by setting all switches to run full time at I_{sm} 12 = 0.4 Amp, or 4. For more complete noise cancellation as a "combiner" species full switch operation is used.

10-30-98

3.1

Claim 1 is for a method for making an implement in species combiner.

Claim 1

The elements, steps and relationships of claim 1 are described with the aid of the examples taken from the specification. A summary is given on annotated page 1:

(a) Title: "Error Correction" by "Selective Modulation"

(c) Reference: U.S. Pat 3,768,011 granted to William H. Swain

(d) Summary.

This invention relates to sensors and/or "implements" for "measurement or control."

The object of the invention is to "improve accuracy" by reducing error in the "sensors output" ("V") when in the presence of an "interfering noise" ("N") source.

The "method" used is usually to find or construct a "sensor" which has a "signal to noise ratio SNR" which changes a lot when its operating parameter ("Q") is "selectively modulated." The output ("V") of the lower noise sensor is combined with the output ("V") of the higher noise sensor so that, in the ideal case, the noise cancels ("at the error corrected output V_c"), but a good signal remains. The easier way may be to take part of the output of the higher noise sensor and subtract ("combine") it from the output of the lower noise sensor. Two sensors can be used, or the operating parameter ("Q") of one sensor can be ("selectively") modulated (driven) from a higher to lower noise state (condition).

11-3-98

An example of an "implement" for "measurement" or "control" is diagrammed in Fig. 9, and discussed on pages 32 to 34 especially. Page 3 introduces Fig. 9:

Fig. 9 is a functional diagram of a switching implementation of the method as stated in a mathematical relationship.

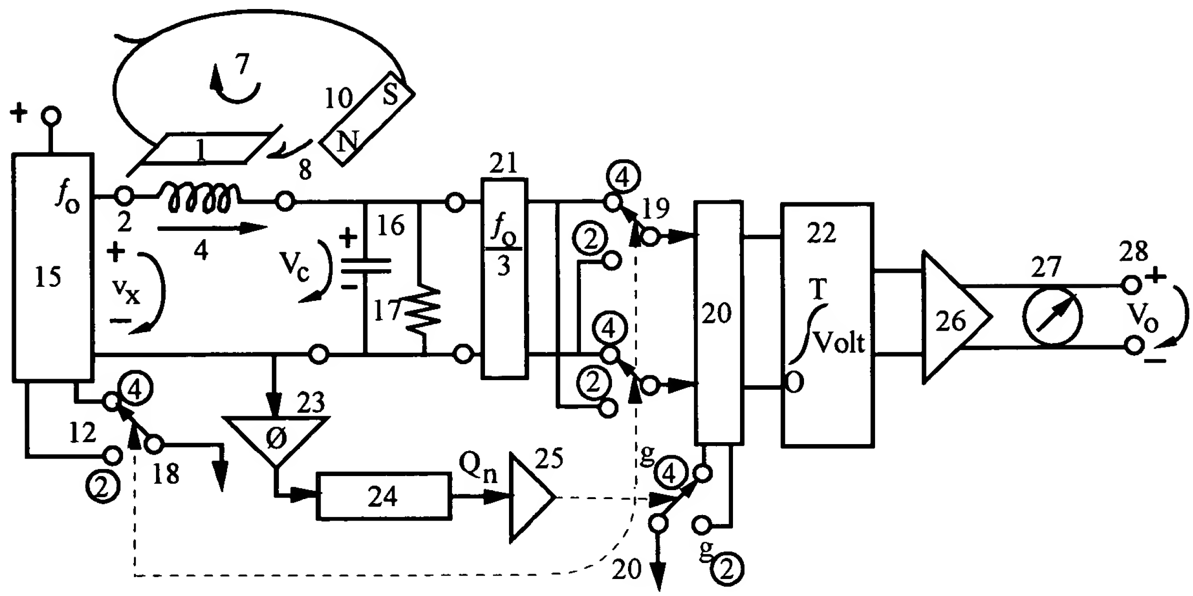


Fig. 9: A switching implementation of the mathematical relationship shown in Eq. i).

Annotated page 32 starts the statement of elements and description of their relationships and functioning. More is given on pages 33 and 34. Timing of steps in function is in Fig. 10.

Fig. 9 starts where the cover drawing (Fig.2) in US Patent 3,768,011 left off. A special inverter is connected in series with the winding 2 on the core 1 of the non-contact sensor. This core 1 may be solid, or split to form a clamp or clip. Capacitor C 16 shunted by resistor R_s 17 are also in series. All are constructed so that the average current I_s 4 flowing in the loop is proportional to the input current I_i 7. Then the average voltage V_c across C 16 and R_s 17 is also proportional to I_i 7. Voltage V_c is the input signal to the corrector.

11-3-98

In Fig. 9 the special inverter 15 operating at frequency f_0 is series connected with the sensor's coupling sense winding 2 and the parallel combination of capacitor 16 and resistor 17. Input current 7 influences the magnetic material in the core 1, and so also does the magnet 10 ("interfering noise N"). So the average current 4 in the loop produces a voltage V_c across capacitor 16 and resistor 17 which is proportional to the input current 7, and also proportional to the effect of noise ("N") magnet 10 and its non-uniform field 8. In this implementation, the means driving the operating parameter I_{sm} (12) from 0.2 to 0.4 Amp. is an electronic switch 18.

Coupling of a "sensor" core SQ 1 to a "signal input I" is illustrated for this example in Fig. 1, shown on annotated page 2 to be:

Fig. 1 is a functional diagram of a sensor with a split magnetic core SQ 1 surrounding a conductor carrying a current I 7 to be measured. The core 1 will have a coupling sense winding N_s 2 if it is to be used as a Swain Meter, or alternatively if it is to be used as a Hall type sensor, one or more Hall devices 5 will replace the winding.

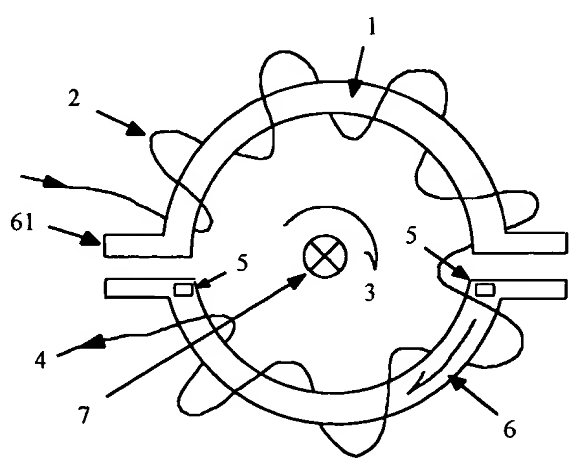


Fig. 1: A clamp-on sensor

11-3-98

Fig. 3 is introduced on annotated page 2:

Fig. 3 illustrates "interference" from the non-uniform 8 magnetic field H_n ("noise N") due to a magnet 10 near the sensor (field 8 couples to core 1).

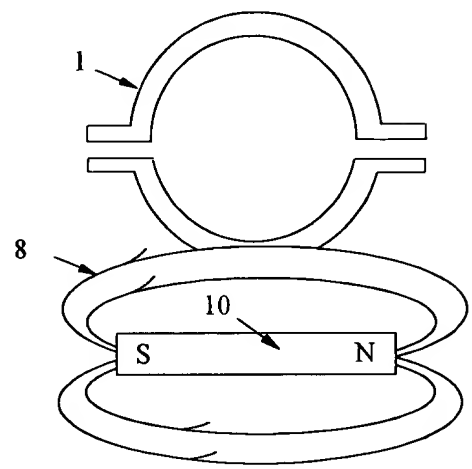


Fig. 3: A non-uniform magnetic field (H_n) 8 ("noise N") from a magnet acting on the core (1 of the "sensor").

The elements comprising

"means whereby said output V of the said sensor in a higher said SNR state due to a condition of said operating parameter Q is combined with said output V of said sensor in a lower said SNR state due to a different said condition of said operating parameter Q, and

adjust said combined so that the said noise N mostly cancels but said sensor continues to have a good gain for said signal input I."

are connected in illustrative example Fig. 9, and their function detailed on pages 32 to 34, with steps timed on Fig. 10.

11-3-98

Fig. 7 provides a graphical view for a broad brush summary of "combine" and "adjust." Annotated page 3 says:

Fig. 7 is a bar graph showing typical relationships between error (due to noise N and gain g for input signal I) etc., before correction of a hypothetical sensor.

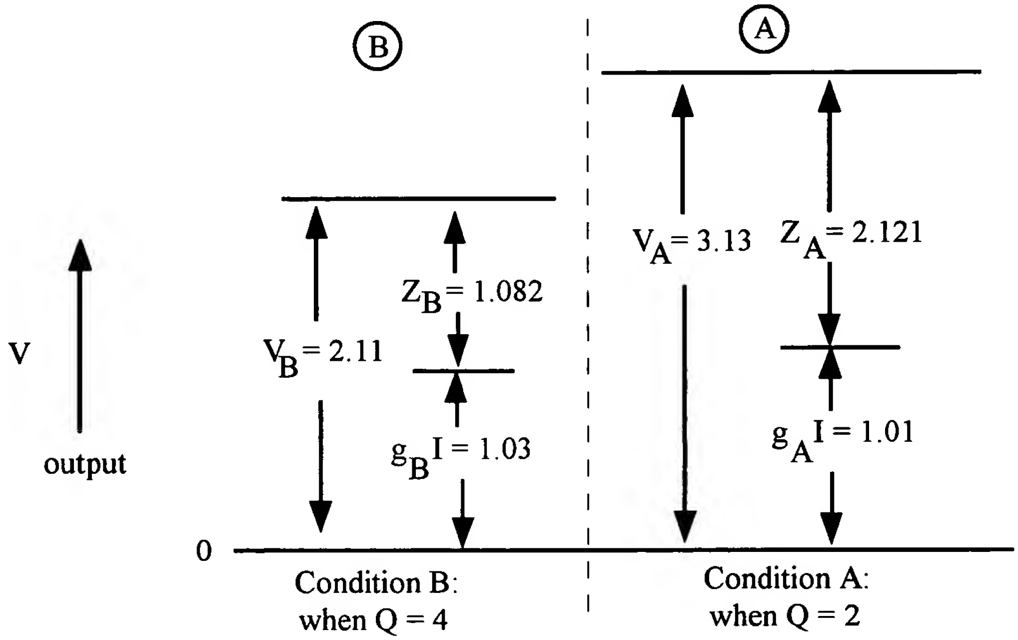


Fig. 7
The illustration displays typical relationships between

error, gain, etc., before correction of a hypothetical sensor.

In Fig. 7, when "operating parameter Q" is "selectively modulated" to Q = 2 in condition A the "sensor" is in a high noise state. The "noise N" produces a sensor "output V" (called Z_A in Fig. 7) a bit over 2 volts.* The response to the desired "signal input I" is called $g_A I$. It is about 1 volt, so the "signal to noise ratio" "SNR" is about ½. The sensor is in a "lower SNR state".

* Output V is said to be in volts. This need not be so, but it is convenient.

11-3-98

At a later time when "operating parameter Q" is "selectively modulated" to Q = 4 in condition B, the "sensor" is in a "higher SNR state". The "noise N" produces a lesser "output V" (called Z_B in Fig. 7) of just over 1 Volt. And the response to the desired "signal input I" (called $g_B I$) is still about 1 Volt. So the "signal to noise ratio" "SNR" is about 1. The "sensor" is in a "higher SNR state".

Now one can see in Fig. 7 how to "combine" the outputs so that "noise N mostly cancels", in "error corrected output V_c". In claim 1, "V_c" is the output of amplifier 26 marked V_0 28 in Fig. 9.

To get "V_c" the output V_A is divided by 2 and then subtracted from the output V_B. Noise Z_A is 2 Volts, so half of it is 1 Volt - the same as the noise Z_B in condition B. So

$$Z_B - \frac{Z_A}{2} \triangleq 0$$

and the noise is "canceled" from the "output V_c" of the "implement".

"Signal input I" produced about 1 volt output in both the "higher SNR state" of "operating parameter" condition B, and also the "lower SNR state" of operating parameter" condition A. So when we divide output V_A by 2 and subtract it from V_B the desired signals are "combined" to form "error corrected output V_c". Thus:

$$"V_c" = g_B I - \frac{g_A I}{2}.$$

Since g_B and g_A are both about equal to one,

$$V_c \triangleq \frac{g_B}{2} I.$$

This shows that the "sensor" "continues to have" "a good gain for signal input I". This "good gain" is $\frac{g_B}{2}$.

11-3-98 / W

If the "sensor" lacked the "essential characteristic" the signal would cancel when the noise canceled. Fortunately, this is not the case in many Swain Meters, and also the Hall ammeter shown in table II and III, and likely in other sensors. Some Hall and Swain sensors have the "essential characteristic."

A Swain example is Fig. 5. It shows that 5" clip #88 was found to have SNR which changed 2 to one (29 to 13) when the operating parameter I_{sm} changed from .4 Amp to .2 Amp. This illustrates that 5" clip #88 has the "essential characteristic." Annotated page 2 introduces Fig. 5:

Fig. 5 is a graph illustrating the "essential characteristic" in terms of "signal to noise ratio SNR" for 5" diameter aperture clip #88.

11-3-98

/ ✓

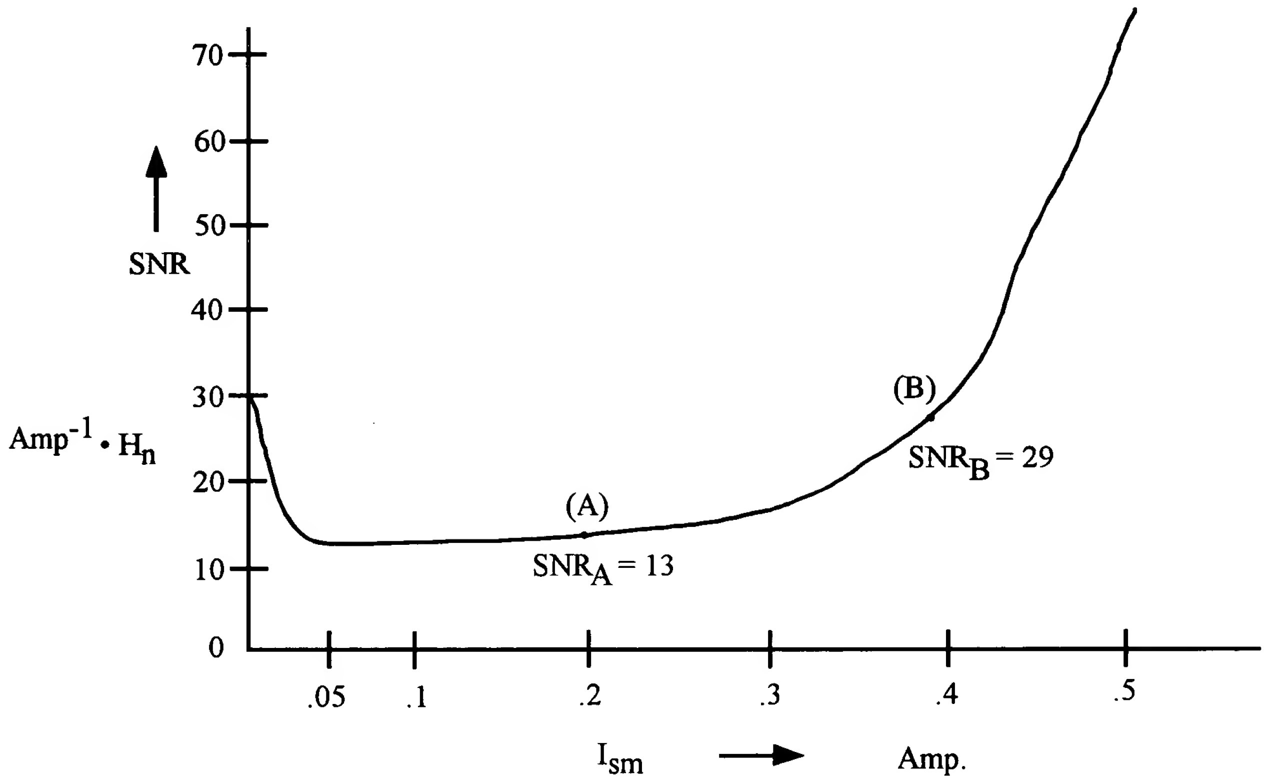


Figure 5

Signal to Noise Ratio (SNR) for Non-Uniform Field H_n

vs.

Operating Parameter I_{sm}

for

5" dia. aperture clip #88 in SN 2336

output

input

$$SNR \equiv \frac{\delta V / \delta I}{\delta V / \delta N} \Big\} \frac{\text{output}}{\text{noise}}$$

$$= \frac{\text{gain}}{\text{gain} \cdot \frac{\delta \acute{O}}{\delta N}} \qquad \frac{Z}{g} = \text{equivalent input offset I}$$

per

unit non-uniform field H_n

11-3-98

3.8

Claim 8 is for an implement with a sensor for measurement or control, in the combiner species.

Claim 8 is for a switching apparatus. It has some elements in common with claims 10, 14, and 16, so detail is available in my discussion of these claims. To illuminate the connections and relationships an example is given in Fig. 9. Timing is shown in Fig. 10. Fig. 5 shows a clip which is used as an example in explaining the interrelationships and functioning and connection of parts.

Page 32 says "Fig. 9 starts" where referenced U.S. Patent 3,768,011, especially Fig. 2 and Fig. 4 left off.

Fig. 9 is a functional diagram of a switching implementation of the method as stated in a mathematical relationship.

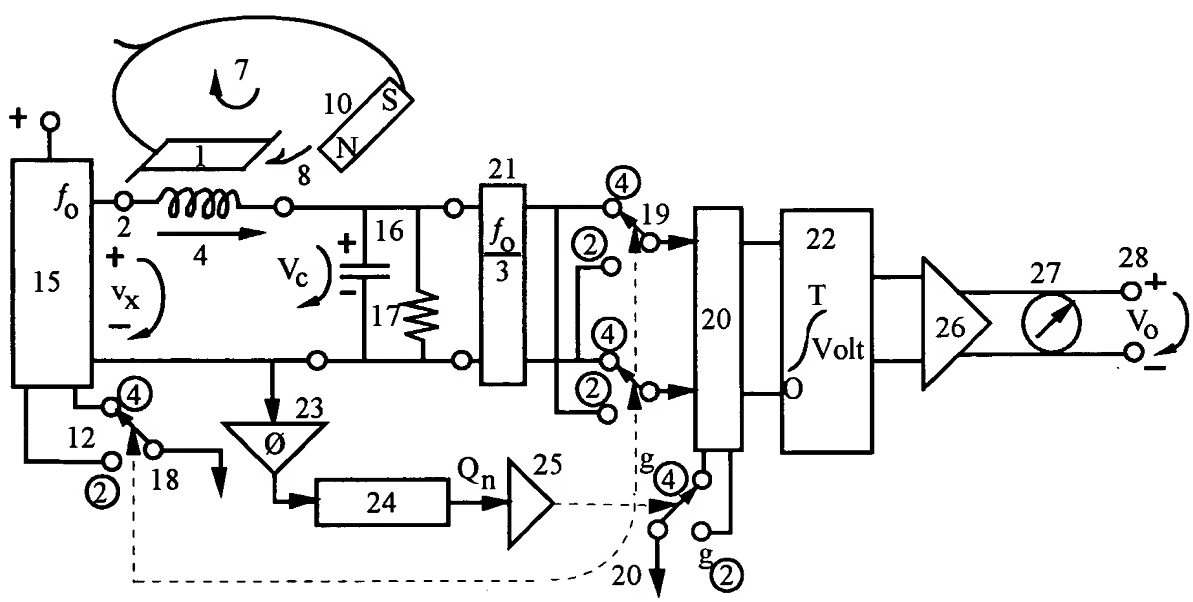


Fig. 9: A switching implementation of the mathematical relationship shown in Eq. i).

In claim 8:

"Implement" is illustrated in Fig. 9 which is captioned "implementation".

10-30-98 8 ll

An example of "sensor" is illustrated in referenced Fig. 2 and 4, as well as present Fig. 1.

Key "sensor" elements which are series interconnected in Fig. 9 include:

Core 1 having winding 2, capacitor 16 shunted by resistor 17, and inverter 15.

"Signal input called I" is 7 in Fig. 9; or 13 in referenced Fig. 4.

"Output V" is V_c across capacitor 16 in Fig. 9; or V_c in referenced Fig. 2.

"Interfering noise source called N" is magnet 10 shown coupled by magnetic field H_n 8 to core 1.

"Inherently or conditioned to be largely constant" refers to: "sample and hold technology can be beneficial in both Fig. 9 and 11. We usually keep it simple and just average the signals." This is from page 35.

"Time duration" and TA + B" are shown on Fig. 10, second frame; plus pages 34 and 35.

"Means" and "largely correct said error" are a good part of Fig. 9, which is detailed on pages 32, 33, 34, and 35, plus Figs. 5, 9, and 10. The timed action and switching steps are summarized on pages 33 and 34;

"In Fig. 9 the noise due to Magnet 10 and interfering field (Hn) 8 is canceled by the process of:" "during (time interval) B, add positive full signal and the small noise Z_4 (outputed when I_{sm} = 0.4A) and then"

"during A, subtract half of the" "twice as large (noise) Z_2 (outputed when I_{sm} = 0.2 A)" and (also subtract) half of the signal."

10-30-98 8

"The noise cancels, but half of the signal remains in the corrected output."

Thus the "means" in Fig. 9 act to "largely correct said error" while "preserving said input" (i.e., signal) "at an output of said implement here called V_c"; where "V_c" is the V_o 28 in Fig. 9.

Page 2 introduces Fig. 4 to show the relationships defining the "essential characteristic."

Fig. 4 is a graph illustrating the essential characteristic discovered in a type of clamp used in some Swain Meters. As the operating parameter I_{sm} increases, the signal gain increases only slightly, but the normalized output zero offset due to noise, here called Ó, first increases and then decreases to half and less.

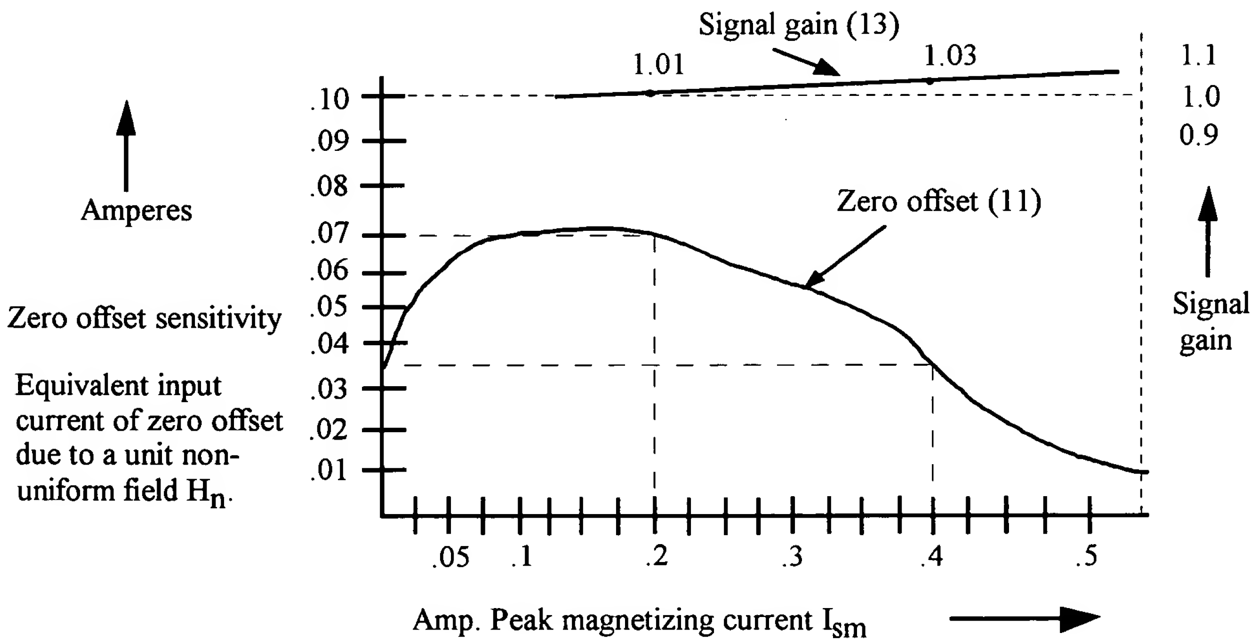


Fig. 4
Normalized Signal Gain (g) vs. I_{sm}
and
Normalized Zero Offset from H_n vs. I_{sm}
for
Five inch diameter aperture sensor #88.

"Essential characteristic" is also defined on page 11 and illustrated in Fig. 5.

10-30-98 8

"Operating parameter Q" and it's effect on SNR is shown in Fig. 8.

"gain g" plus "noise sensitivity Ψ" are interrelated with operating parameter Ism in the above Fig. 4, and in the Discovery statement on page 11. The "selective modulator" is the device which "changes" the "condition of an operating parameter Q."

In claim 8 the remaining elements, relationships, and steps are explained in claim 8 itself, or in pages 32 through 37.

10-30-98

8

3.10

Claim 10 is for a method for constructing apparatus for correcting error in the combiner species. It is for at least one of a single sensor which switches SNR state, or two sensors, each operating continuously in one SNR state.

In claim 8 I claim a noise canceling apparatus using a single sensor having it's operating parameter Q switched (selectively modulated) from a higher SNR condition (state) at a first time to a lower SNR condition at another time.

In claim 10 I claim a method for constructing a noise canceling apparatus having one sensor and some elements and relationships similar to those already described in relation to claim 8, and,

alternatively, two sensors used simultaneously at different conditions of the operating parameter so that continuous operation results and high speed data is available.

The elements, connections and relationships for claim 10 are described by way of example and illustration of a particular process of making in the specification on Fig. 4, 5, 9, 10, and 11, and also on pages 1, and 31 through 38; in addition to the reference patent 3,768,011; Fig. 2 and 4 especially.

Page 1 states elements and relationships broadly:

(a) Title: "Error Correction" by Selective Modulation

(c) Reference: U.S. Pat 3,768,011 granted to William H. Swain

(d) Summary.

This invention relates to sensors and/or implements ("apparatus") for "measurement or control."

11-2-98 18 cc

The object of the invention is to improve accuracy by reducing ("correcting") "error" in the "sensors output" ("V") when in the presence of an "interfering noise" ("N") source.

The method used is usually to find or construct ("choose or manufacture") a "sensor" which has a "signal to noise ratio SNR" which changes a lot when its "operating parameter Q" is "selectively modulated M." The "output V" of the lower noise sensor is "combined" with the output of the higher noise sensor so that, in the ideal case, the noise cancels, but a good signal remains. The easier way may be to take part of the output of the higher noise sensor and "subtract" it from the output of the lower noise sensor. Two sensors can be used, or the operating parameter of one sensor can be modulated (driven) from a higher to lower noise state.

If there is one sensor, the operating cycle time is generally reduced to less than the time during which the signal and noise can be constrained to be constant. However, if "two sensors" or a combination are used, there is little need to keep signal and noise constant.

The operation of the elements in claim 10 and their relationships are illustrated using Fig. 9, introduced on page 3 as:

Fig. 9 is a functional diagram of a switching implementation of the method as stated in a mathematical relationship.

11-2-98

10 ✓

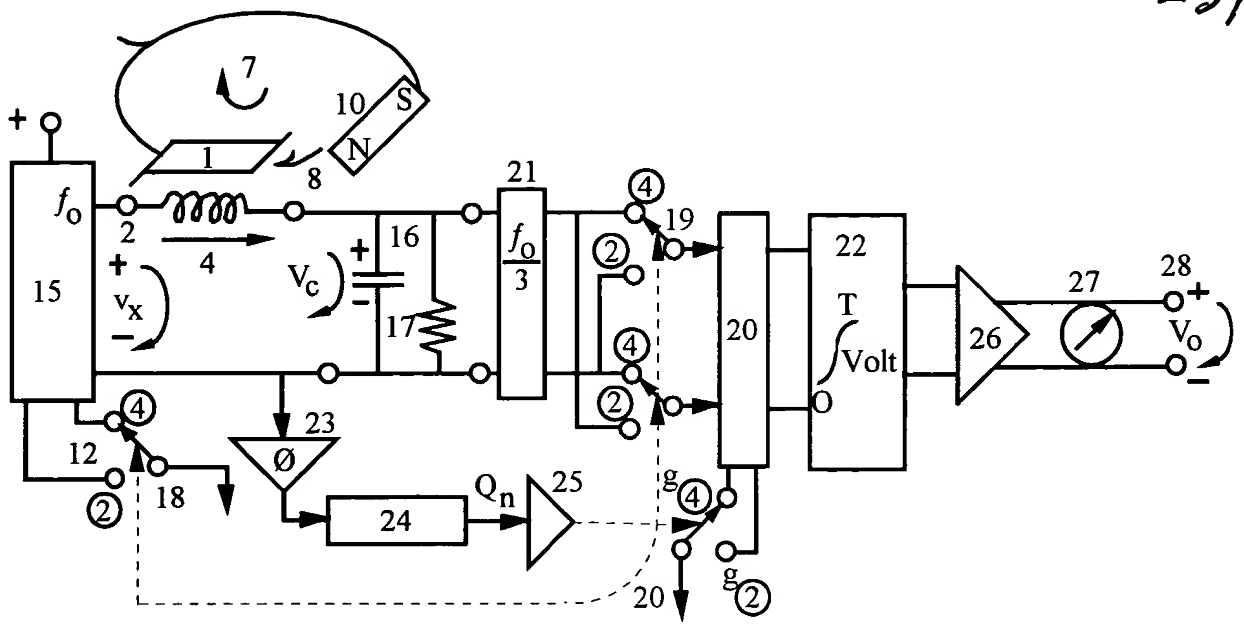


Fig. 9: A switching implementation of the mathematical relationship shown in Eq. i).

Fig. 9 is an example of "apparatus". Magnet 10 and "noise N" field 8 act on core 1 so as to cause a zero offset "error' at the "output V" of the "sensor" - here V_c across C_{16}. The "sensor" includes core 1 with sense winding 2, inverter 15 and low impedance capacitor 16 shunted by resistor 17, series connected as in Fig. 9 with average current 4 flowing.

A "physical quantity", in this example, electric "signal input I" current 7 (current in wire 13 in reference Fig. 4) is to be measured or controlled.

"Error" is corrected by use of the "process" called "selective modulation" which is applied to a "sensor" having the "essential characteristic" as shown in Fig. 5.

Page 2 introduces Fig. 5:

Fig. 5 is a graph illustrating the "essential characteristic" in terms of "signal to noise ratio SNR" for 5" diameter aperture clip #88.

11-2-98

10 ✓

40

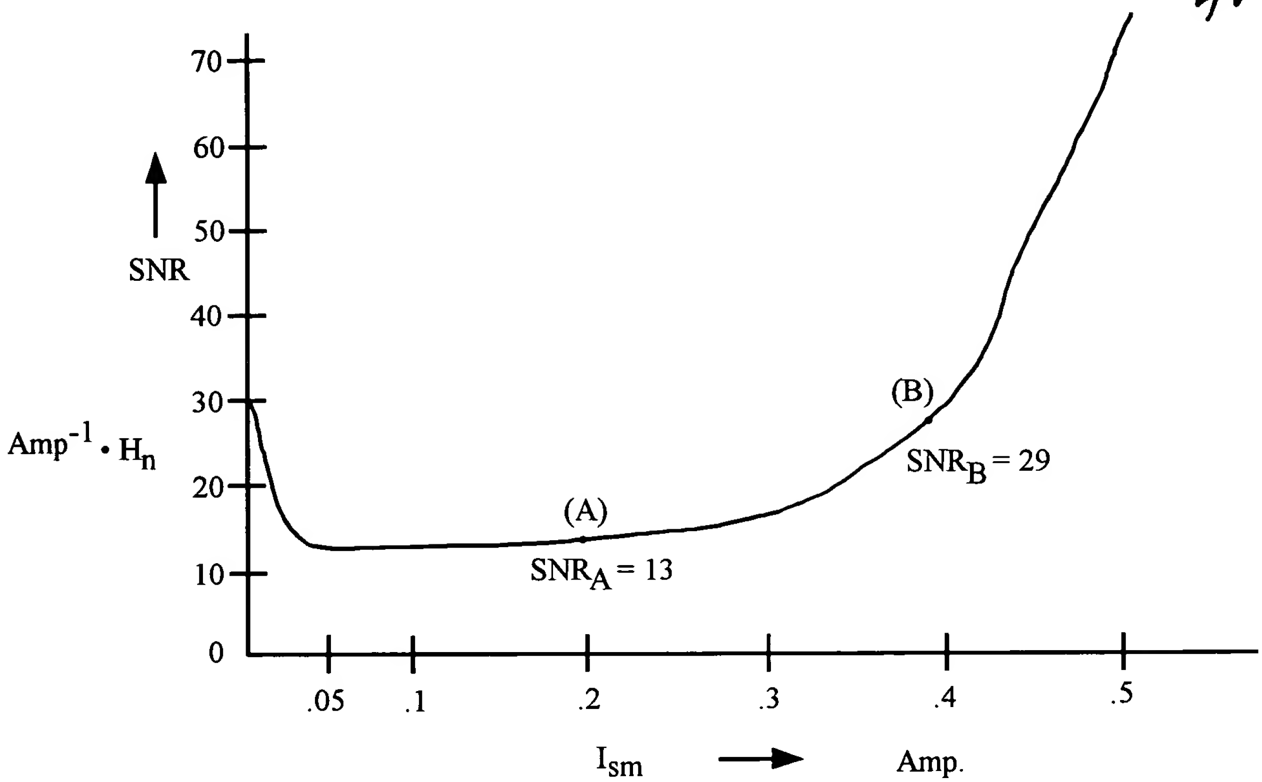


Figure 5

Signal to Noise Ratio (SNR) for Non-Uniform Field H_n

vs.

Operating Parameter I_{sm}

for

5" dia. aperture clip #88 in SN 2336

$$SNR \equiv \frac{\overset{\text{output}}{\delta V} / \overset{\text{input}}{\delta I}}{\delta V / \delta N} \Big\} \frac{\text{output}}{\text{noise}}$$

$$= \frac{\text{gain}}{\text{gain} \bullet \frac{\delta \acute{O}}{\delta N}} \qquad \frac{Z}{g} = \text{equivalent input offset I per unit non-uniform field } H_n$$

Fig. 5 relates "output V"/input I ("desired signal input I"); together with "output V"/ "interfering noise N" to "SNR". Since in claim 10, $1/\Psi$ = SNR, this relates all to "sensitivity to noise N", which is "Ψ".

11-2-98

The relationships between "SNR", "operating parameter", "selective modulation" and other elements or processes are summarized on page 13 which states:

The "essential characteristic" necessary for good error correction by "selective modulation" can be measured and presented in several ways, but that shown in Fig. 5 - the plot of "SNR" vs. "Operating Parameter" is now considered the most basic. A good characteristic such as that in Fig. 5 has a substantial change in SNR - two to one or more - over a practical range of the condition of the "operating parameter". It is not necessary that the gain g be nearly constant. Good "correction" can be had when the gain g changes 40% as the "operating parameter Q" is driven from one condition to another.

In Fig. 5 we may use "two sensors" of similar structure, likely in close proximity to one another and both coupled to the input I and noise N, but operated continuously to different operating parameters ("conditions") - one Q = 2 and the other Q = 4. Then the one has "SNR_A" continuously and the other has "SNR_B" continuously.

Pages 33 and 34 further summarize and define and relate "subtract" "corrected output", and more.

In the example of Fig. 9, I illustrate the interconnections needed to correct the noise error due to magnet 10 and interfering field (H_n) 8 by the process of: during B, add positive full signal and the small noise Z_4 and then during A, "subtracting" half of the twice as large Z_2 and half of the signal. The noise cancels, but half of the signal remains in the ("error") "corrected output". This V_c in claim 10 appears as meter 27 and output V_o 28 in the above Fig. 9.

11-2-98

10

3.12

Claim 12 is for a "method' for "constructing" a "sensor" in the "better SNR" species using Swain Meter concepts.

The 21 Dec. 95 abstract of the disclosure, annotated, says:

(h) Abstract of the Disclosure.

The accuracy of certain sensors is greatly improved by improving their signal to noise ratio (SNR) in the presence of an interfering noise. Sensors were discovered which have a SNR which substantially changes when an "operating parameter" is selectively modulated to different magnitudes. Some noise can be practically eliminated. In the simplest form, (better SNR species), the sensor is operated where it is both stable and close to its best SNR. This is usually faster and less costly, but the noise is never completely eliminated.

Page 3 introduces Fig. 7:

Fig. 7 is a bar graph showing typical relationships between error, gain, etc., before correction of a hypothetical sensor.

"Output voltage V_c" due to "signal current I" is marked gI - i.e., V_c equals gain times input I.

"Output voltage V_c" zero offset error due to "magnetic field noise N is marked Z.

These voltages add to give the total output V in Fig. 7.

There are 2 states or conditions, A & B. Condition A is for "operating parameter I_{sm}" = 2 (0.2 Amp), whereas condition B is for "I_{sm}" = 4 (0.4 Amp).

11-3-98 12 W

Pages 16 to 19 specify the elements, steps and relationships in constructing the "sensor" of claim 12. Annotated Fig. 7 is a summary.

Condition B	Condition A
$g_B I = 1.03$ signal	$g_A I = 1.01$ signal
$Z_B = 1.082$ noise	$Z_A = 2.121$ noise
$SNR_B = .95$	$SNR_A = .48$
Use	Reject

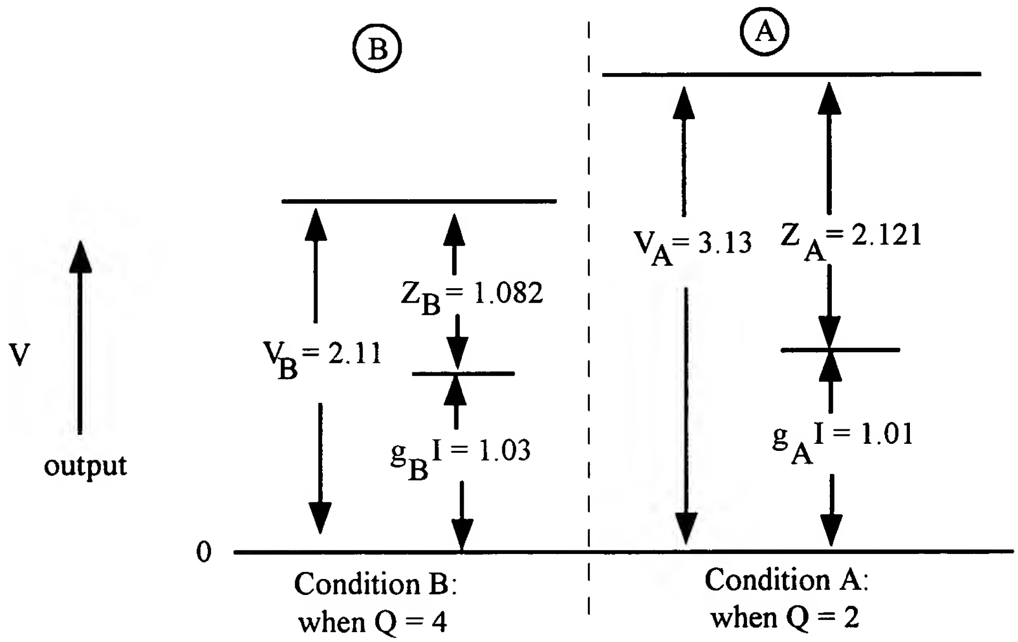


Fig. 7
The illustration displays typical relationships between "error", "gain", etc., before correction of a hypothetical sensor.

Condition B is to be used continuously. Here "zero offset error" Z_B is "reduced" by "adjusting" the "means" "including N_s and I_{sm} so that the "sensor" has low "noise sensitivity."

Interconnections of elements are illustrated in the example shown in Fig. 9. Since it is for the combiner species we only use the condition B elements, so Fig. 9 can be simplified to Fig. 9R which is an example for the better SNR species.

An illustration of "means enabling" "at least one of" is shown in the following (Fig. 9R) reduced form of Fig. 9.

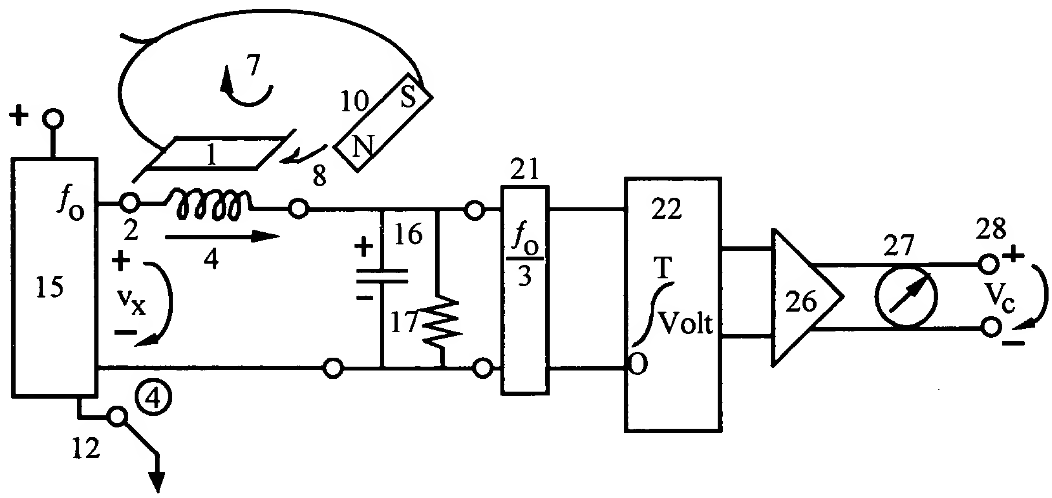


Fig. 9R. Reduced form of Fig 9 to illustrate an example of a species better SNR sensor. "Operating parameter" 12 I_{sm} ("Q") is set at 0.4 Amp 4. The "improved machine" is adjusted to run continuously at point (B) in Fig. 5 where SNR is twice as good as at point (A).

"Machine output V_c" (meter 27 and V_c 28) is more useful because noise (equivalent input offset current I due to non-uniform magnetic field H_n) is less, "accuracy" is better. "Speed of response", "per unit dollar cost", "power consumption", "volume", and "weight" are likely more. Useful because complexity is reduced and design simplified in several ways.

Page 33 especially describes elements removed from Fig. 9. Remaining elements are described, mostly on annotated page 32 as follows:

11-3-98 12 JJ

Fig. 9R starts where the cover drawing (Fig.2) in US Patent 3,768,011 left off. A special inverter is connected in series with the "N_S" "winding" 2 on the core 1 of the non-contact sensor. This core "SQ" may be solid, or split to form a clamp or clip. "Low input impedance means" capacitor C 16 shunted by resistor R_S 17 are also in series. All are constructed so that the "average current I_S" flowing in the loop "series connecting" is proportional to the input current I_i. Then the average voltage across C 16 and R_S 17, which is the "sensor output V" is also proportional to I_i.

In Fig. 9 the special inverter 15 operating at frequency f_O is series connected with the sensor's coupling "sense winding" 2 and the parallel combination low impedance means converting of capacitor 16 and resistor 17 to get "sensor output V." Input signal current 7 influences the magnetic material in the core 1, and so also does the magnet "N" 10 and magnetic field noise 8. So the average I_S current 4 in the loop produces a voltage across capacitor 16 and resistor 17, i.e., the "sensor output V" which is proportional to the input "signal" current 7, and also proportional to the effect of noise "N" magnet 10 and its non-uniform "magnetic" field noise N 8. In this implementation, the means driving the "operating parameter I_{sm}" is set at 0.4 Amp.

Annotated page 2 introduces Fig. 4 which shows element relationships in this illustrative example.

Fig. 4 is a graph illustrating the "essential characteristic" discovered in a type of clamp used in some Swain Meters. As the "operating parameter I_{sm}" ("Q") increases, the signal gain increases only slightly, but the normalized output zero offset due to noise, here called Ó, first increases and then decreases to half and less.

11-3-98

-46-

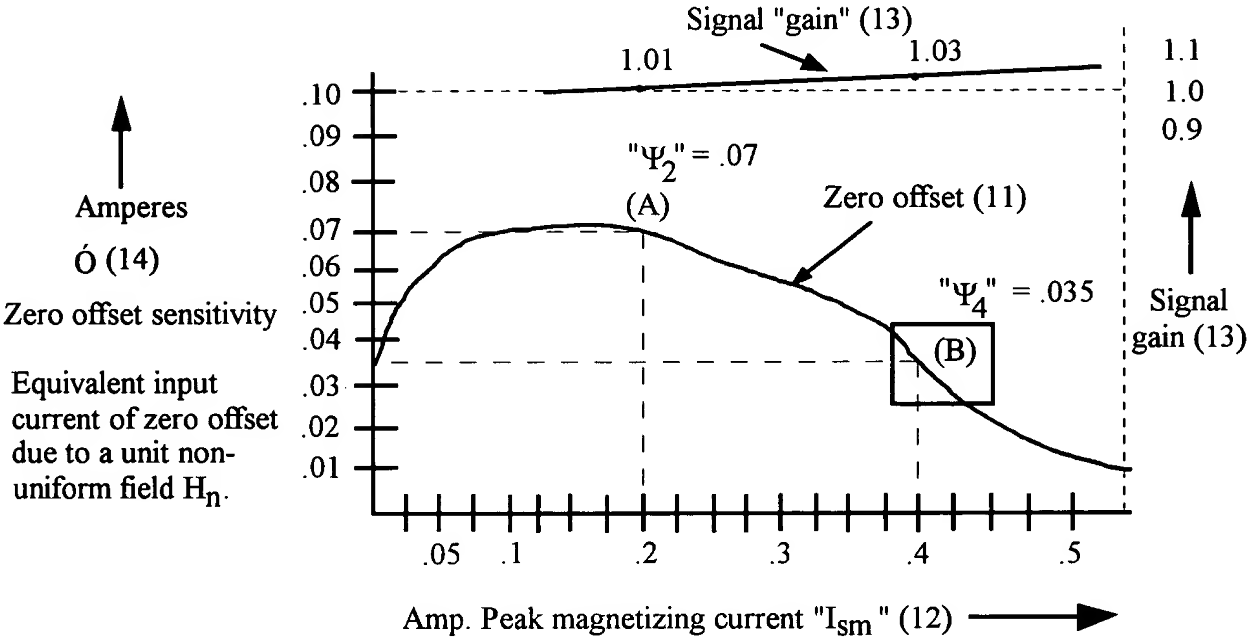


Fig. 4
Normalized Signal Gain (g) vs. "I_{sm}"
and
Normalized Zero Offset from H_n vs. I_{sm}
for
Five inch diameter aperture sensor #88.

The "reduced error" preferred - use - point is B, where I_{sm} = 0.4 Amp, and Ψ_B is "reduced" - Ψ_B = .035, half the noise at point A.

Annotated page 36 says:

Fig. 4 plots the equivalent input current of the zero offset "noise sensitivity" Z due to a standard magnet as a function of "I_{sm}", the "peak current" in the coupling sense winding N_s. This 0.2 to 0.4 Amp peak current is flowing in N_s = 1000 turns on a 5" diameter core, "SQ." What really counts is the peak magnetic field intensity H_{sm} acting on the steel of the core. Since $H_{sm} = \frac{"N_s I_{sm}"}{l}$, where l is the mean flux path length, we can reduce I_{sm} if we increase N_s , or reduce l, etc.

11-3-98

3.13

Claim 13 is for apparatus using Swain Meter concepts for measurement and control. It is in the better SNR species.

The 21 Dec. 95 abstract of the disclosure, annotated, says:

<u>(h) Abstract of the Disclosure.</u>

The "accuracy" of certain (non-contact direct current ammeter) sensors ("for measurement or control") is greatly improved by improving their signal to noise ratio (SNR) in the presence of an interfering noise. Sensors were discovered which have a SNR which substantially changes when an "operating parameter" is selectively modulated to different magnitudes. Some noise can be practically eliminated. In the simplest form, (better SNR species), the sensor is operated where it is both stable and close to its best SNR. This is usually faster and less costly, but the noise is never completely eliminated.

A sensor is more accurate if SNR is high because it is more able to reject zero offset error due to "interfering magnetic noise N."

Page 3 introduces Fig. 7:

Fig. 7 is a bar graph showing typical relationships between error, gain, etc., before correction of a hypothetical sensor.

"Output voltage V_C" due to "signal current I" is marked gI - i.e., V_C equals gain times input I.

"Output voltage V_C" zero offset error due to "magnetic field noise N is marked Z.

11-3-98

These voltages add to give the total output V in Fig. 7.

There are 2 states or conditions, A & B. Condition A is for "operating parameter I_{sm}" = 2 (0.2 Amp), whereas condition B is for "I_{sm}" = 4 (0.4 Amp).

Pages 16 to 19 specify the elements, steps and relationships in constructing the "sensor" of claim 13. Annotated Fig. 7 is a summary.

Condition B	Condition A
$g_B I = 1.03$ signal	$g_A I = 1.01$ signal
$Z_B = 1.082$ noise	$Z_A = 2.121$ noise
$SNR_B = .95$	$SNR_A = .48$
Use	Reject

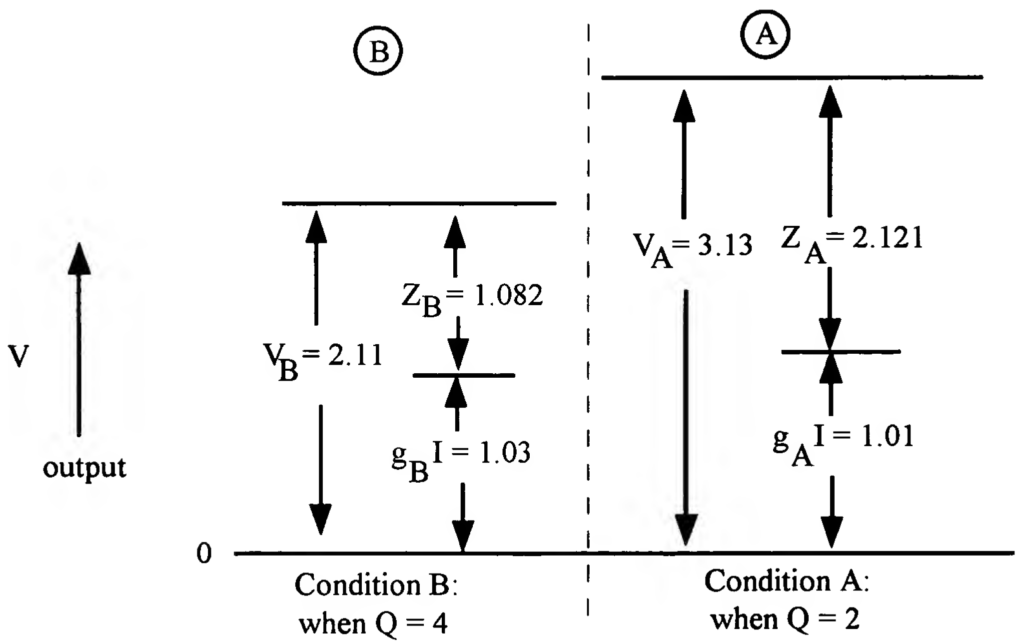


Fig. 7
The illustration displays typical relationships between "error", "gain", etc., before correction of a hypothetical sensor.

11-3-98

Condition B is to be used continuously. Here "zero offset error" Z_B is "reduced" by "adjusting" the "means" "including N_s and I_{sm} so that the "sensor" has low "noise sensitivity."

Interconnections of elements are illustrated in the example shown in Fig. 9. Since it is for the combiner species we only use the condition B elements, so Fig. 9 can be simplified to Fig. 9R which is an example for the better SNR species.

An illustration of "means enabling" "at least one of" is shown in the following (Fig. 9R) reduced form of Fig. 9.

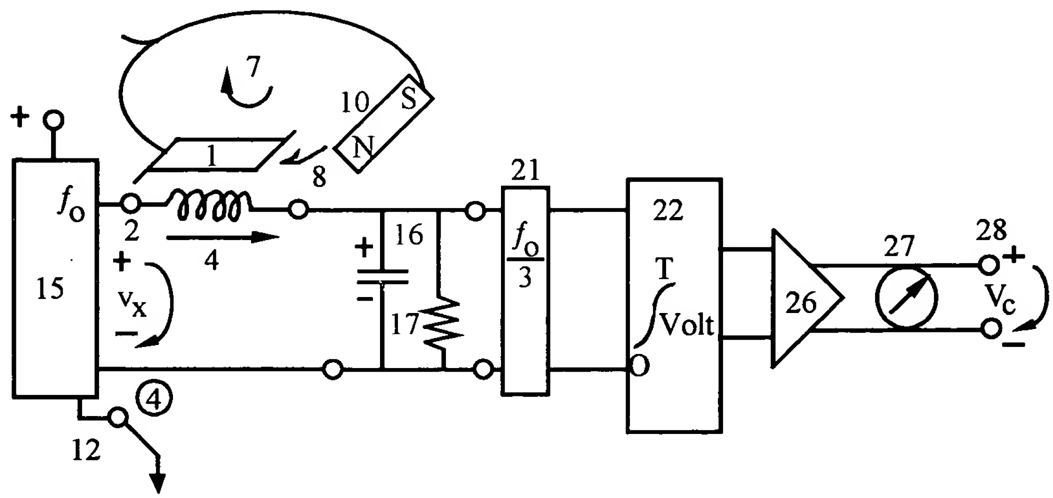


Fig. 9R. Reduced form of Fig 9 to illustrate an example of a species better SNR sensor. "Operating parameter" 12 I_{sm} ("Q") is set at 0.4 Amp 4. The "improved machine" is adjusted to run continuously at point (B) in Fig. 5 where SNR is twice as good as at point (A).

"Machine output V_c" (meter 27 and V_c 28) is more useful because noise (equivalent input offset current I due to non-uniform magnetic field H_n) is less, "accuracy" is better. "Speed of response", "per unit dollar cost", "power consumption", "volume", and "weight" are likely more. Useful because complexity is reduced and design simplified in several ways.

11-3-98

Page 33 especially describes elements removed from Fig. 9. Remaining elements are described, mostly on annotated page 32 as follows:

Fig. 9R starts where the cover drawing (Fig.2) in US Patent 3,768,011 left off. A special inverter 15 is connected in series with the "N_S" "winding" 2 on the core ("SQ") 1 of the "non-contact" sensor. This core "SQ" may be solid, or split to form a clamp or clip. Core SQ 1 is "positioned" so that input "current I_i" "influences" its' magnetic state. "Core SQ" is also "within the effective range" of "magnetic field noise N." These are shown in Fig. 1 and Fig. 3.

"Low input impedance means" capacitor C 16 shunted by resistor R_S 17 are also in series. All are constructed so that the "average current I_S" flowing in the loop "series connecting" is proportional to the input current I_i 7. Then the average voltage across C 16 and R_S 17, which is the "sensor output V" is also proportional to I_i.

In Fig. 9R the special "inverter" 15 operating at frequency f_0 is series connected with the sensor's coupling "sense winding" 2 and the parallel combination low impedance means converting of capacitor 16 and resistor 17 to get "sensor output V." Input signal current 7 influences the magnetic material in the core 1, and so also does the magnet "N" 10 and magnetic field noise 8. So the average I_S current 4 in the loop produces a voltage across capacitor 16 and resistor 17, i.e., the "sensor output V" which is proportional to the input "signal" current ("I") 7, and also proportional to the effect of noise "N" magnet 10 and its non-uniform "magnetic" field noise N 8.

In this implementation, the means driving the "operating parameter I_{sm}" is set at 0.4 Amp.

Annotated page 2 introduces Fig. 4 which shows element relationships in this illustrative example.

11-3-98

Fig. 4 is a graph illustrating the "essential characteristic" discovered in a type of clamp used in some Swain Meters. As the "operating parameter I_{sm}" ("Q") increases, the signal gain increases only slightly, but the normalized output zero offset due to noise, here called Ó, first increases and then decreases to half and less.

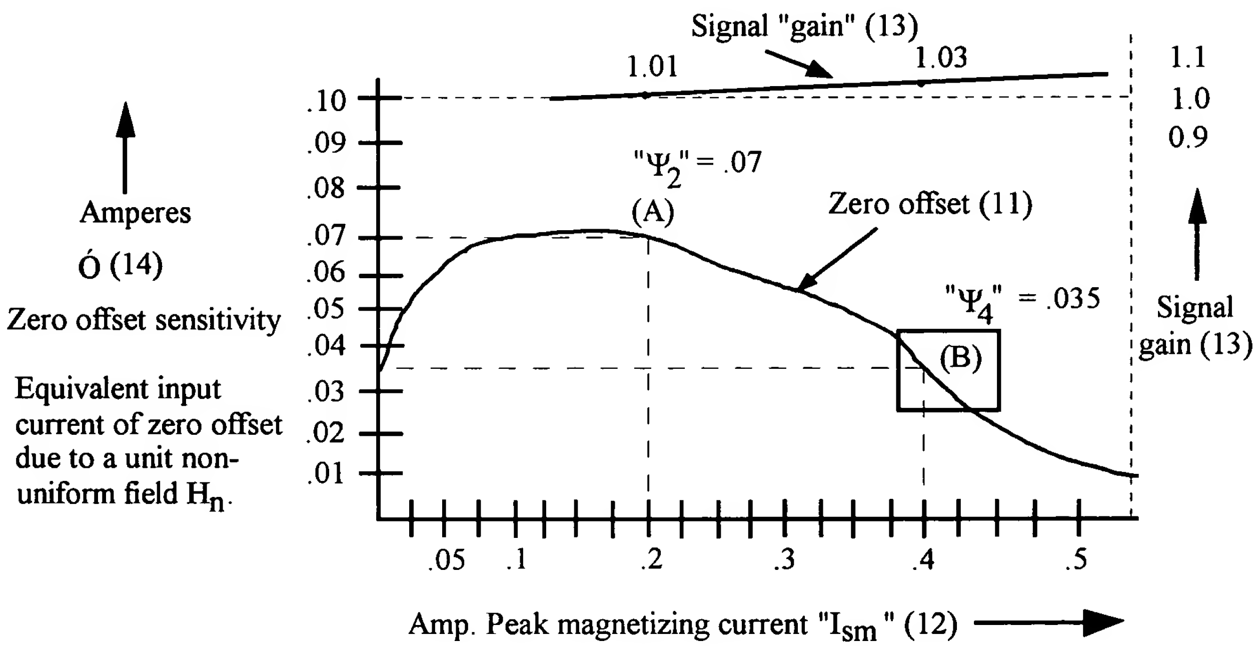


Fig. 4
Normalized Signal Gain (g) vs. "I_{sm}"
and
Normalized Zero Offset from H_n vs. I_{sm}
for
Five inch diameter aperture sensor #88.

"Operating parameter I_{sm} is set to a substantially greater magnitude" - 0.4 Amp at Point B - "than the magnitude" - 0.2 Amp at Point A - "corresponding to the minimum SNR" - i.e., maximum zero offset sensitivity Ψ. Note $\Psi = \frac{1}{SNR}$.

In other words: the "reduced error" preferred - use - point is B, where I_{sm} = 0.4 Amp, and Ψ_B is "reduced" - Ψ_B = .035, half the noise at point A where I_{sm} = 0.2 Amp peak in sensor current i_s.

11-3-98

13

Annotated page 36 says:

Fig. 4 plots the equivalent input current of the zero offset "noise sensitivity" Z due to a standard magnet as a function of "I_{sm}", the "peak current" in the coupling sense winding N_s. This 0.2 to 0.4 Amp peak current is flowing in N_s = 1000 turns on a 5" diameter core, "SQ." What really counts is the peak magnetic field intensity H_{sm} acting on the steel of the core. Since $H_{sm} = \frac{"N_s I_{sm}"}{l}$, where l is the mean flux path length, we can reduce I_{sm} if we increase N_s , or reduce l, etc.

11-3-98

3.15

Claim 15 is for a "better" SNR species apparatus. It is often simpler to construct than the usual "combiner" species, partly because it improves SNR by 2 or 3 times for H_n type noise, but does not cancel the noise. As page 1 of the specification says:

In a simpler form, ("better SNR" species) SNR is substantially improved by operating at a more favorable operating parameter magnitude. Noise is not canceled, but this can be faster and cost less.

Annotated page 4 briefly defines and relates elements of the "sensor" in a "machine":

Method and Means

It was discovered that certain "sensors" have a sensitivity (responsiveness) to an ("undesired") interfering "noise" ("N") which changes a great deal more ("substantially altered") than the sensitivity to a signal input ("physical quantity I") when the magnitude of an "operating parameter" ("Q") is changed. We call this "selective modulation". The noise ("interference N") can be due to a change in the strength of a magnetic field, heat or cold, pressure of a fluid, etc.

The word sensitivity implies that the sensor has an "output V".

The caption of Fig. 5 defines "SNR" in terms of "physical quantity I" (Input I); "output V" (output V), "undesired interference N" (non-uniform field H_n), and more.

11-3-98

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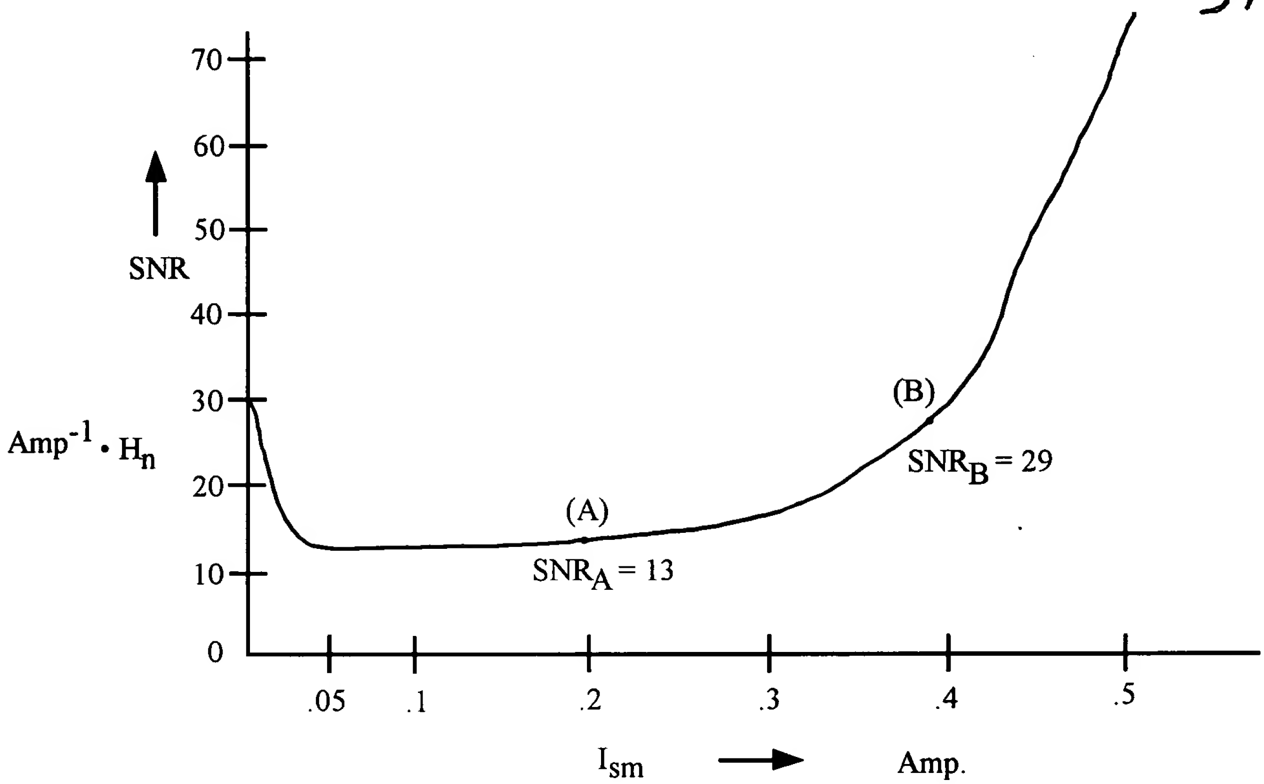

Figure 5
Signal to Noise Ratio (SNR) for Non-Uniform Field H_n
vs.
Operating Parameter I_{sm}
for
5" dia. aperture clip #88 in SN 2336

output, input

$$SNR \equiv \frac{\delta V / \delta I}{\delta V / \delta N} \Big\} \frac{\text{output}}{\text{noise}}$$

$$= \frac{\text{gain}}{\text{gain} \cdot \frac{\delta \acute{O}}{\delta N}} \leftarrow \frac{Z}{g} = \text{equivalent input offset I per unit non-uniform field } H_n$$

Fig. 5 is a graph illustrating the "essential characteristic" in terms of signal to noise ratio SNR for 5" diameter aperture clip #88.

The above title on page 2 for Fig. 5 shows that it also illustrates the "essential characteristic" - namely "SNR" is changed a lot (from 13 to 29) - i.e. - "substantially altered" by the change - i.e. -

"selective modulation" in the magnitude of "operating parameter Q" - i.e. - I_{sm} - from 0.2 Amp to 0.4 Amp.

An illustration of "means enabling" "at least one of" is shown in the following (Fig. 9R) reduced form of Fig. 9.

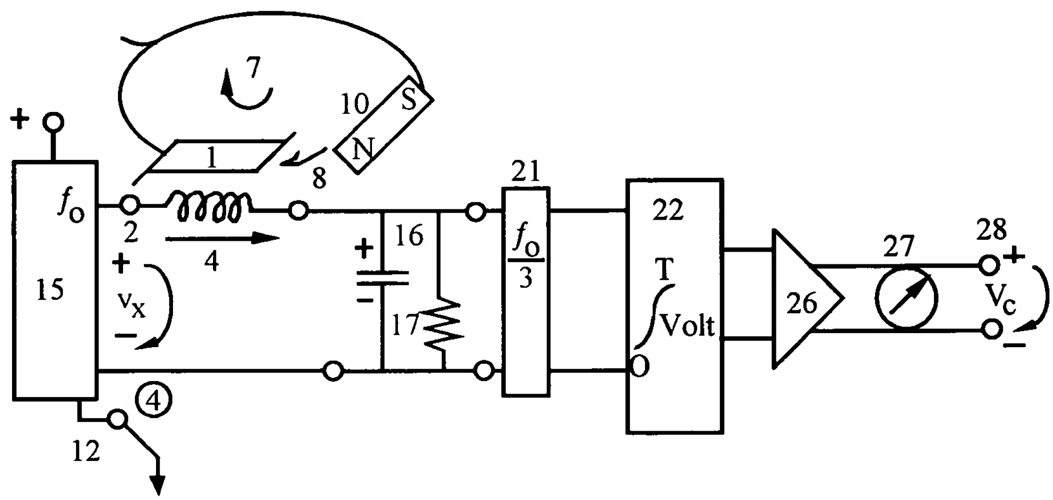

Fig. 9R. Reduced form of Fig 9. to illustrate an example of a species better SNR sensor. "Operating parameter" 12 I_{sm} ("Q") is set at 0.4 Amp 4. The "improved machine" is adjusted to run continuously at point (B) in Fig. 5 where SNR is twice as good as at point (A).

"Machine output V_c" (meter 27 and V_c 28) is more useful because noise (equivalent input offset current I due to non-uniform magnetic field H_n) is less, "accuracy" is better. "Speed of response", "per unit dollar cost", "power consumption", "volume", and "weight" are likely more. Useful because complexity is reduced and design simplified in several ways. Page 33 especially describes elements removed from Fig. 9. Remaining elements are described, mostly on page 32.

11-3-98

Claim 16

Claim 16 is for apparatus in species combiner.

A summary of elements and relationships appears on page 4. For better understanding of claim 16 I have earlier presented much detail in connection with claim 14 and others. Particularly and briefly for claim 16 I refer to the specification for illustrations and examples.

Page 1 (annotated) says:

This invention relates to "sensors" and/or "implements" ("machines") for "measurement or control".

The object of the invention is to improve "accuracy" by reducing error in the "sensors output (V)" when in the presence of an "interfering" noise ("N") source.

Page 2 (annotated) states:

"Sensors" with implements ("machines") using this invention have better "accuracy" because the "SNR" is generally improved by 2 to 20 times - typically ten times. (In an illustrative example) this benefit is typical of Swain type clamp-on DC ammeters subject to "interfering" noise ("N") from non-uniform magnetic fields.

Further, on page 4 (annotated);

The means for doing this are called implements ("machines"), or "sensor" with implement. They may also be called transducers or signal transducers.

A further example is Fig. 9. It diagrams a "machine" for "measuring or controlling." It's title is:

Fig. 9: A switching implementation ("machine") of the mathematical relationship shown in Eq. i).

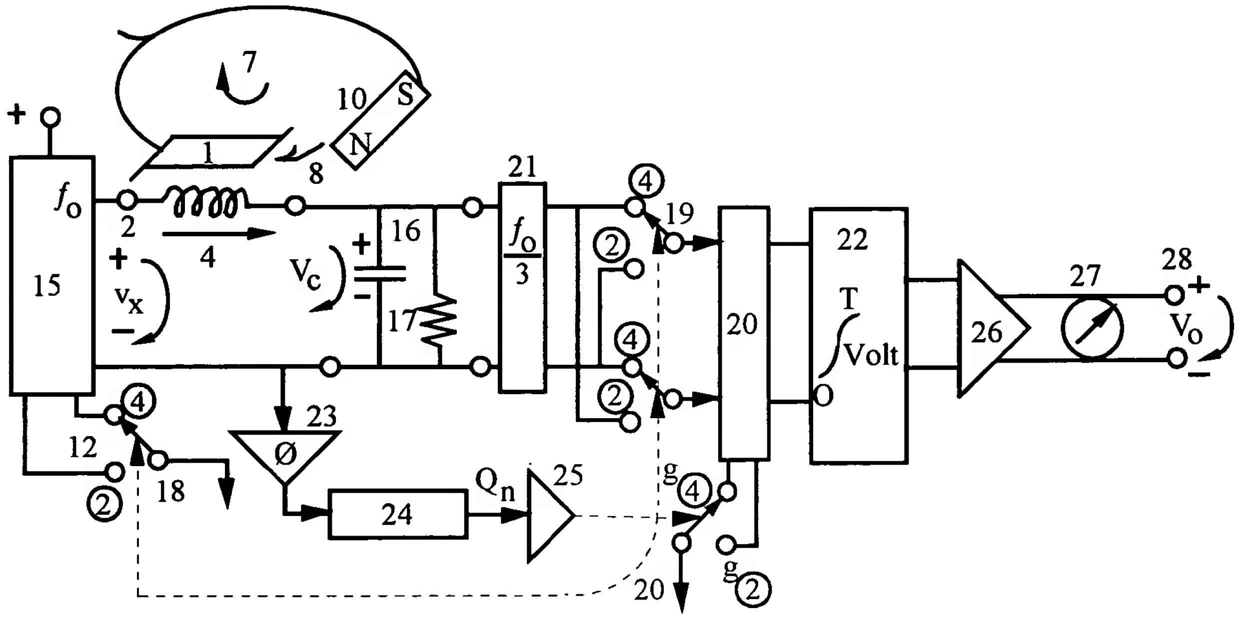

Fig. 9: A switching implementation of the mathematical relationship shown in Eq. i).

Page 32 (annotated) begins the detail of elements and interconnections in Fig. 9.

Fig. 9 starts where the cover drawing (Fig. 2) in (referenced) U.S. Patent 3,768,011 left off.

In Fig. 9 the special inverter 15 operating at frequency f_o is series connected with the sensor's coupling sense winding 2 and the parallel combination of capacitor 16 and resistor 17. Input current 7 influences the magnetic material in the core 1, and so also does the magnet 10. So the average current 4 in the loop produces a voltage V_c ("sensor" "output" voltage "V") across capacitor 16 and resistor 17 which is proportional to the input current 7, and also proportional to the effect of noise magnet 10 and its non-uniform field 8. In this implementation, the means driving the operating parameter I_{sm} (12) from 0.2 to 0.4 Amp. is an electronic switch 18 ("selective modulation").

For this illustration, pages 32 thru 35 and Fig. 10 specify the steps, timing, and relationships of the elements which operate on the "output V", (V_c across capacitor 16 in Fig. 9) to produce "machine output V_c" which is labeled: meter 27 and V_o 28 at the right of Fig. 9.

Page 35 (annotated) states:

The "2" and "4" states (conditions) in time intervals Ⓐ and Ⓑ alternate, and the integrator 22 averages the output packets of both to give one long term average output. This is amplified 26 to produce the output V_o 28 ("machine output V_c") for data logging, etc., and driving the ("machine") output meter 27. The user can read the ("physical quantity I") input current I_i 7 and not be troubled by the noise ("N") of zero shift error Z due to magnet 10 ("undesired interference N") because it has been largely removed by the above error correction.

"Responsiveness" is inherent in the captions beneath Fig. 5. Here "signal to noise ratio" "SNR" is defined using δV/δI with "output (V)" per input ("physical quantity I"), plus δV/δN, i.e., ("output V") per noise ("interference N") due to non-uniform (magnetic) field H_n.

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-59-

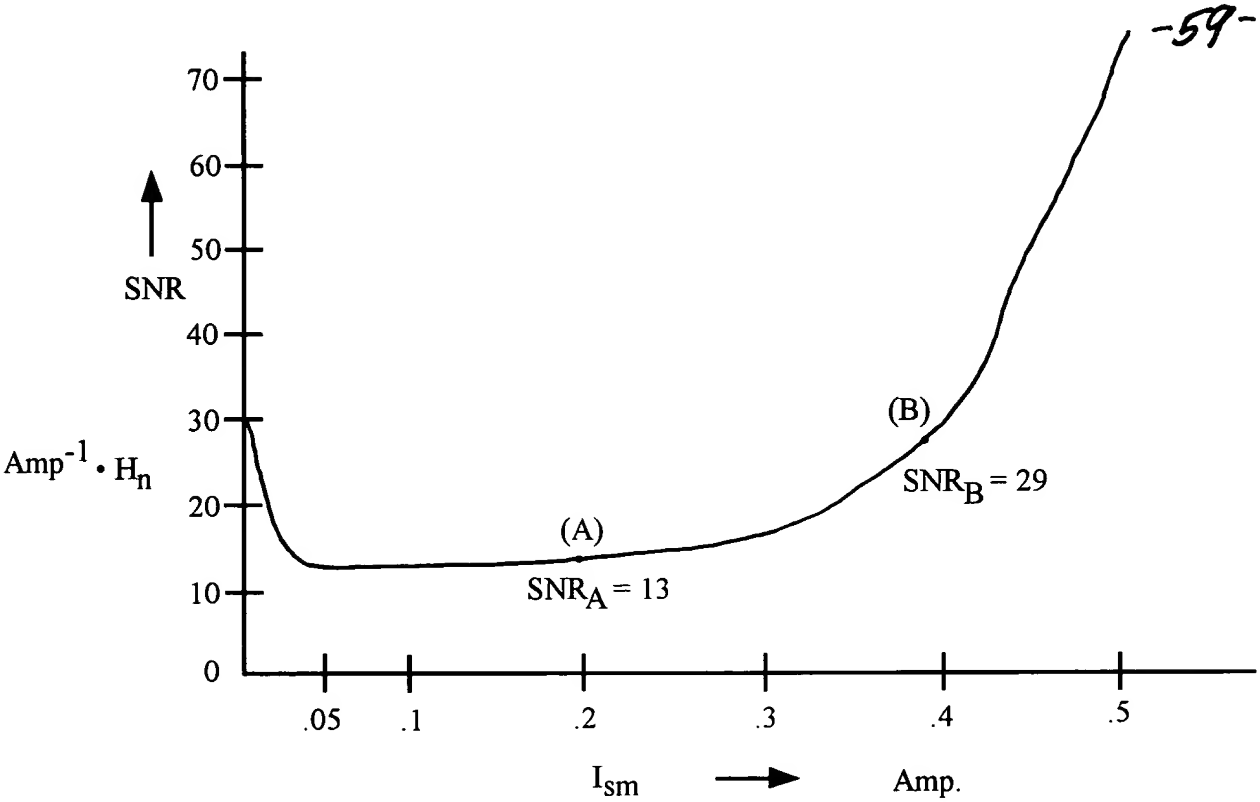

Figure 5
Signal to Noise Ratio (SNR) for Non-Uniform Field H_n
vs.
Operating Parameter I_{sm}
for
5" dia. aperture clip #88 in SN 2336

output
input

$$\mathrm{SNR} \equiv \frac{\delta V / \delta I}{\delta V / \delta N} \Big\} \frac{\text{output}}{\text{noise}}$$

$$= \frac{\text{gain}}{\text{gain} \cdot \frac{\delta \acute{O}}{\delta N}} \qquad \frac{Z}{g} = \text{equivalent input offset I per unit non-uniform field } H_n$$

The title for the example Fig. 5 on page 2 says that Fig. 5 illustrates the "essential characteristic". Thus:

11-2-98

Fig. 5 is a graph illustrating the "essential characteristic" in terms of signal to noise ratio SNR for 5" diameter aperture clip #88.

Annotated page 16 further defines "essential characteristic" in terms of "responsiveness to a "physical quantity I" and an "interference N", thus:

The signal to noise ration (SNR) changes a lot ("is substantially altered") when an operating parameter Q changes its "condition"*. By this I mean that the signal gain g (43) changes only a few percent when the operating parameter Q (42) changes enough to cause the noise sensitivity Ψ (45) to change by a factor of two or more, or vice versa.

By SNR I mean the sensitivity of the sensor's output V to the signal I divided by that to noise interference Ψ.

In Eq. b) $\frac{\delta V}{\delta I} = g$, and

In Eq. g) $\frac{\delta V}{\delta N} = g\Psi$, so

$$\text{SNR} = \frac{g}{g\Psi}\text{, or}$$

Eq. l) $\text{SNR} = \frac{1}{\Psi}$

* Operating parameter Q can be any of a variety of physical quantities able to change condition ("be selectively modulated"). It can be a chemical mixture proportion, electric current, fluid pressure, etc. The change in the condition of Q can be a magnitude, as in peak current I_{sm} changing condition from .2 to .4 Amp. Or it can be a change in power supply voltage or source impedance, a change in frequency used in a modulator, a change in direction of an applied force, etc.

11-2-98

Operating parameter Q can be thought of as an input to a modulator, or as the modulator itself. Functionally a change in Q causes a change in the SNR of the sensor.

"Higher" and "lower" "SNR state" are defined and related to other elements in connection with the illustrative example Fig. 5 and Fig. 9 on pages 23 and 24. Thus:

If it is elected to correct error by switching from one state to another as discussed in connection with the implementation of Fig. 9 or Fig. 11 the essential characteristic in Fig. 4 can be summarized in Table I.

State (condition) Ⓐ is the higher noise state because the zero offset Z is greater when a standard magnet is present. This is shown in Table I by Ψ_2 in state Ⓐ, which is double Ψ_4 in state Ⓑ. State Ⓑ is the low state noise.

Table I

("Higher SNR") (Low noise state) | ("Lower SNR") (Higher noise state)

Table I

	State Ⓑ	State Ⓐ	Ratio
Point on graph	(B)	(A)	
I_{sm}	0.4	0.2	
gain	$g_4 = 1.03$	$g_2 = 1.01$	Characteristics
Noise sensitivity	$\Psi_4 = 0.035$	$\Psi_2 = 0.07$	of 5" clip #88.

The above I_{sm} is the "operating parameter Q" which is "selectively modulated" from 0.2 to 0.4.

11-2-98 11

"Combined" is illustrated and defined on page 17 as:

. Two points (A) and (B) are selected in Fig. 6 and Fig. 8. Conditions before error correction in these two states Ⓐ and Ⓑ, are shown in bar graph form in Fig. 7. The objective is to combine the two outputs V_B and V_A so that the noise error components Z_B and Z_A cancel, but a good part of the input signal components $g_B I$ and $g_A I$ remain. One way to do this is by subtracting part of V_A from V_B.

"Means enabling..." so that "interference N" is "mostly removed" from "machine output V_c" but... "good responsiveness" to "physical quantity I" are illustrated in the example of Fig. 9.

Above quoted page 17 uses the word "cancel" for "mostly removed". The "means" is likely "subtracting".

"Means enabling..." is further defined - elements stated - steps named, timing shown in pages 33-35 and Fig. 10.

A <u>summary</u> statement of the above is given on page 4:

Error Correction by Selective Modulation

Method and Means

It was discovered that certain "sensors" have a sensitivity to an "interfering" noise which changes a great deal more than the sensitivity to a signal input when the magnitude of an "operating parameter" is changed. We call this "selective modulation." The noise can be due to a change in the strength of a magnetic field, heat or cold, pressure of a fluid, etc.

A method of "improving" "accuracy" is to divide down the "sensors output" when it is in a "high noise state", retain and later subtract this from the "sensors output" when it is in a "low

noise "state so that the noise largely cancels, but a "good" signal remains. This may be the simplest process for "combining" sensor outputs. A process for doing this is given in a general mathematical relation, and in more specific forms derived therefrom. The means for doing this are called implements, or "sensor" with implement. They may also be called transducers or signal transducers.

11-2-98

16

Claim 17 is a process of making a combiner species of my invention. All elements, steps, and relationships are illustrated by examples given in connection with claim 16.

The summary given below covers the most important aspect.

"Error Correction" by "Selective Modulation"

Method and Means

It was discovered that certain "sensors" have a sensitivity to an "interfering" noise which changes a great deal more than the sensitivity to a signal input when the magnitude of an "operating parameter" is changed. We call this "selective modulation." The noise can be due to a change in the strength of a magnetic field, heat or cold, pressure of a fluid, etc.

A method of "improving" "accuracy" is to divide down the "sensors output" when it is in a "high noise state", retain and later subtract this from the "sensors output"when it is in a "low noise "state so that the noise largely cancels, but a "good" signal remains. This may be the simplest process for "combining" sensor outputs. A process for doing this is given in a general mathematical relation, and in more specific forms derived therefrom. the means for doing this are called implements, or "sensor" with implement. They may also be called transducers or signal transducers.

3.26

Claim 26 is for a process of constructing machinery in the combiner species.

"Combining" is at least one of:

done continuously using the output of 2 sensors, each operated full time at different operating parameters; and

full time "combining" the output of a single sensor as it is selectively modulated from condition A to condition B, and back again.

Elements, steps, and relationships are summarized with the help of illustrative examples given in the specification.

Page 1 (annotated) provides a general view:

"Error Correction" by "Selective Modulation"

This invention relates to "sensors" and/or implements ("machine") for "measurement or control."

The object of the invention is to improve accuracy by reducing ("correcting") error in the "sensors" "output" ("V_c") when in the presence of an "interfering noise" ("N") source.

The method ("process") used is usually to find or construct a "sensor" which has a "signal to noise ratio SNR" which changes a lot when its "operating parameter" ("Q") is "selectively modulated". The output of the lower noise sensor is "combined" with the output of the higher noise sensor so that, in the ideal case, the noise cancels ("error is corrected"), but a good signal ("physical quantity I") remains. The easier way may be to take part of the output of the higher

26 //

11-2-98

noise sensor and subtract it from the output of the lower noise sensor. "Two sensors" can be used, or the "operating parameter" of one sensor ("said sensor") can be modulated (driven) from a higher to lower noise state.

If there is one sensor ("said sensor"), the operating cycle time is generally reduced to less than the "time during" which ("when") the signal ("physical quantity I") and noise ("N") can be constrained to be "constant." However, if "two sensors" ("sensor A and sensor B") or a combination are used, there is little need to keep signal and noise constant.

A summary of method ("process") and "means" on page 4 (annotated) says:

<u>**Method ("process") and "Means"**</u>

It was discovered that certain sensors have a sensitivity to an "interfering noise" ("N") which changes a great deal more than the sensitivity to a signal input ("physical quantity I") when the magnitude of an "operating parameter" is changed. We call this "selective modulation" ("M"). The noise can be due to a change in the strength of a magnetic field, heat or cold, pressure of a fluid, etc.

A method of improving accuracy is to "divide" down the sensors output ("V") when it is in a high noise (high "Ψ") state, retain and later subtract this from the sensors output when it is in a low noise (low "Ψ") state so that the noise largely cancels ("error is corrected"), but a good signal remains. This may be the simplest process for combining sensor outputs. A process for doing this is given in a general mathematical relation, and in more specific forms derived therefrom. The means for doing this are called implements ("machines"), or sensor with implement. They may also be called transducers or signal transducers.

Relations, "essential characteristic", "gain g", "sensitivity to noise N", and more are illustrated in the example in Fig. 4, its caption, and its (annotated) title, which reads:

Fig. 4 is a graph illustrating the "essential characteristic" discovered in a type of clamp ("sensor") used in some Swain Meters ("machine"). As the "operating parameter" I_{sm} ("Q") increases, the signal gain ("g") increases only slightly, but the normalized "output" ("V") zero offset ("error") due to noise ("N"), here called Ó, first increases and then decreases to half and less.

Fig. 4, its caption, and page 11 provide an example - the performance of 5" clip #88 in a Swain Meter "machine" - to illustrate the relationships "essential characteristic", "zero offset sensitivity" "Ψ", and more.

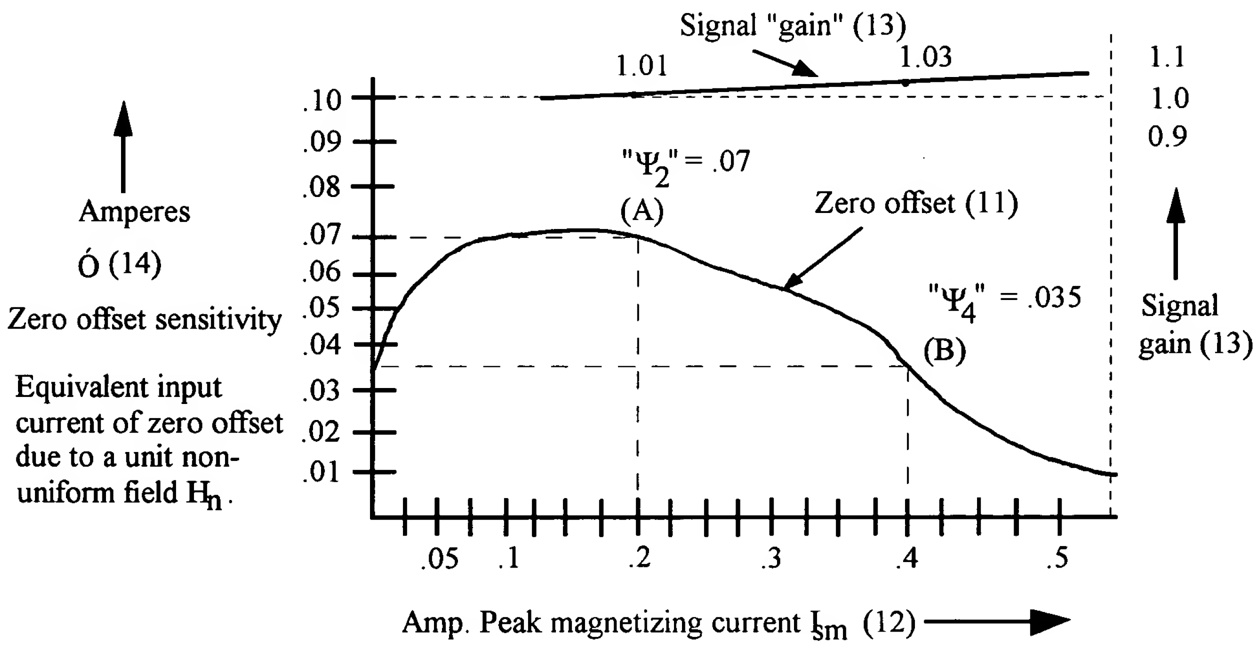

Fig. 4

Normalized Signal "Gain (g)" vs. I_{sm}
and
Normalized Zero Offset from H_n vs. I_{sm}
for
Five inch diameter aperture sensor #88.

"Essential Characteristic"

Fig. 4 shows the approximate sensitivities for a five inch diameter aperture clip #88. This is an illustration of a sensor having the "essential characteristic":

Firstly, the signal gain g (13) sensitivity to signal input I (7) is constant within a few percent as an operating parameter I_{sm} (12) changes from 0.18 A to 0.5 Amp peak; and

Secondly, the zero offset (11) sensitivity to a unit change in intensity of a non-linear magnitude field H_n (8) is reduced to well under half over the same range of I_{sm} (12).

The equation relating these quantities is $V = gI + Z$.

V is "sensor output V."

I is "physical quantity I." Z is "error."

The symbols Ó, Ψ, (Ψ = Ó/N), input I (7), and I_{sm} (12) refer to pages 12 & 13 and Fig. 9 which connect the elements in this illustrative example.

Zero offset is given in terms of Ó=Z/g, where the input current I ("physical quantity I") equivalent to the zero offset Z is obtained by dividing the zero offset Z ("error") by the signal gain g. The result Ó (14) is plotted in Fig. 4.

The data in Fig. 4 shows the approximate behavior of 5" dia. aperture clip #88. It uses concepts shown in referenced Patent 3,768,011, especially in connection with Fig. 2 and Fig. 4 therein. Clip #88 is outlined in Fig. 1 herein.

Fig. 9 is functional diagram of a switching implementation of the method as stated in a mathematical relationship.

11-2-98

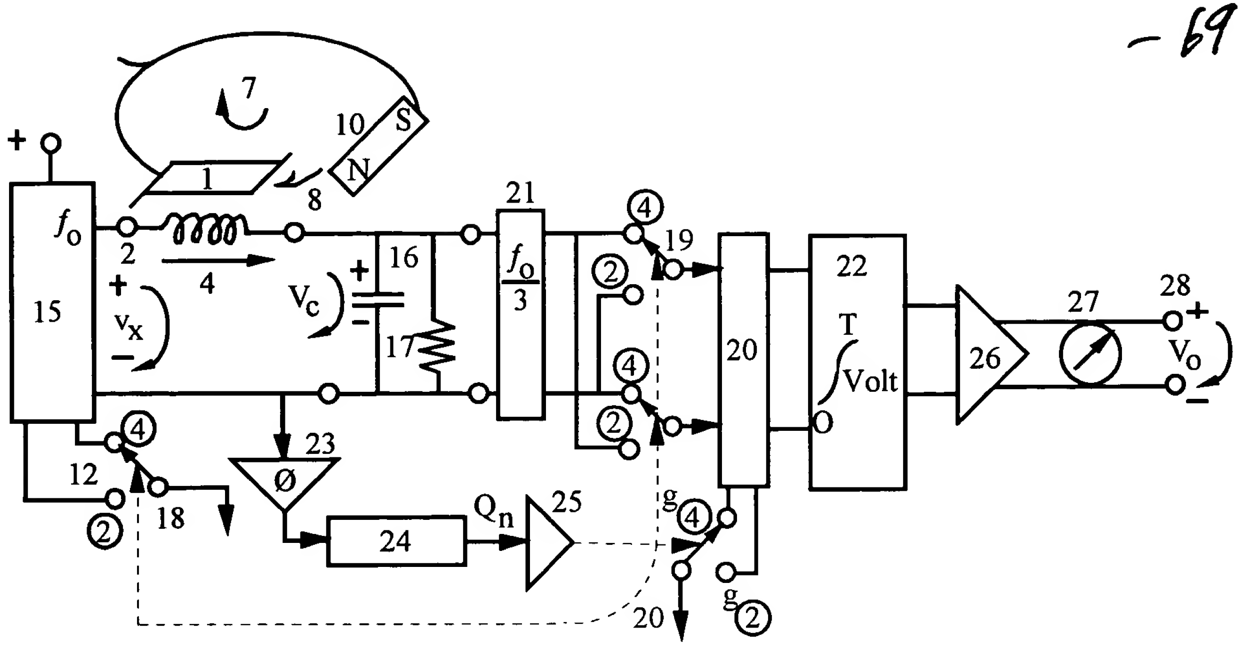

Fig. 9: A switching implementation of the mathematical relationship shown in Eq. i).

In "machine" example Fig. 9 above, V_c across capacitor 16 is an illustration of "sensor output V" in claim 26. In Fig. 9 above, meter 27 and V_o 28 are illustrations of "machine" "output V_c" in claim 26.

Operation steps, and more for the example of Fig. 9 are specified on pages 32 to 35.

11-2-98

26

3.28 -70-

Claim 28 is for a "process" for "constructing" a sensor in the "Better SNR" "species" using Swain Meter technology similar to that in referenced U.S. Patent 3,768,011.

Page 1 of the 21 Dec 95 application says:

In a simpler form, SNR is substantially improved by operating at a more favorable operating parameter magnitude. Noise ("error") is not canceled, but this form can be faster and cost less.

An illustrative example is Fig. 9R shown below. This is Fig. 9 cut down to include elements and means needed to "construct" a "Better SNR" species "sensor".

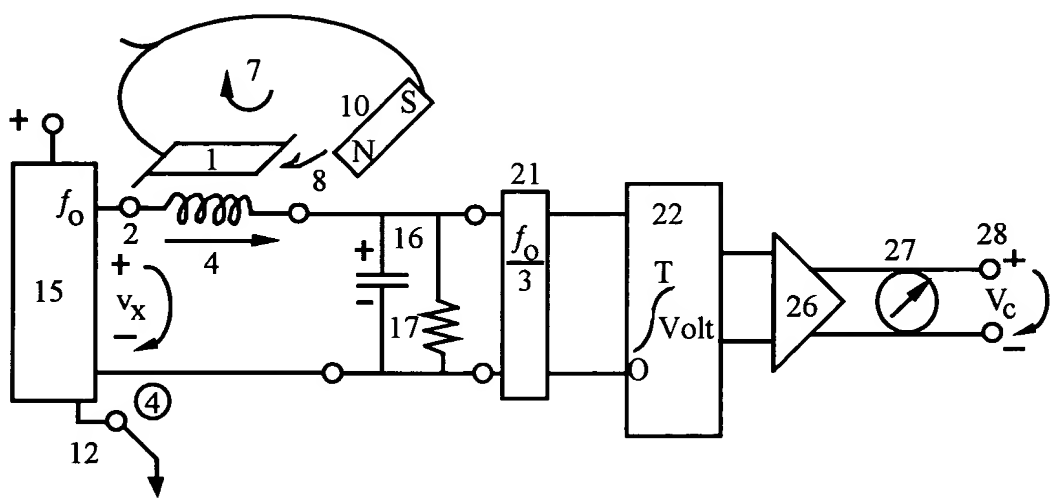

Fig. 9R. This is a reduced form of Fig. 9.

Elements and relationships in Fig. 9R are described on pages 32 and 33, plus Fig. 1, 3, and 5. "Output voltage "V_C" is element 28.

Page 32 (annotated) says:

Fig. 9 starts where the cover drawing (Fig.2) in US Patent 3,768,011 left off. A special "inverter" is connected in "series" with the winding on the core of the non-contact "sensor." This

11-2-98 28

core may be solid, or split to form a clamp or clip. Capacitor C shunted by resistor R_S are also in "series." All are constructed so that the average current I_S flowing in the loop is proportional to the input current I_i. Then the average voltage V_C across C and R_S is also proportional to I_i. Voltage V_C is the input signal to the corrector.

In Fig. 9 the special inverter 15 operating at frequency f_O is series connected with the sensor's "coupling sense winding 2" and the parallel combination ("low impedance means") of capacitor 16 and resistor 17. Input current 7 influences the magnetic material in the core 1, and so also does the magnet 10. So the "average" "current" 4 in the loop produces a voltage V_C across capacitor 16 and resistor 17 which is proportional to the input current 7, and also proportional to the effect of noise magnet 10 and its non-uniform field 8. In this implementation, ...the "operating parameter I_{sm}" (12)... is set at 0.4 Amp.

Fig. 1 shows the core and other "sensor" elements and their relative positions. It's annotated title says:

Fig. 1 is a functional diagram of a "sensor" with a split "magnetic" "core" "SQ" surrounding a conductor carrying a ("signal") current I to be measured. The core will have a coupling sense winding "N_S" if it is to be used as a Swain Meter, or alternatively if it is to be used as a Hall type sensor, one or more Hall devices 5 will replace the winding.

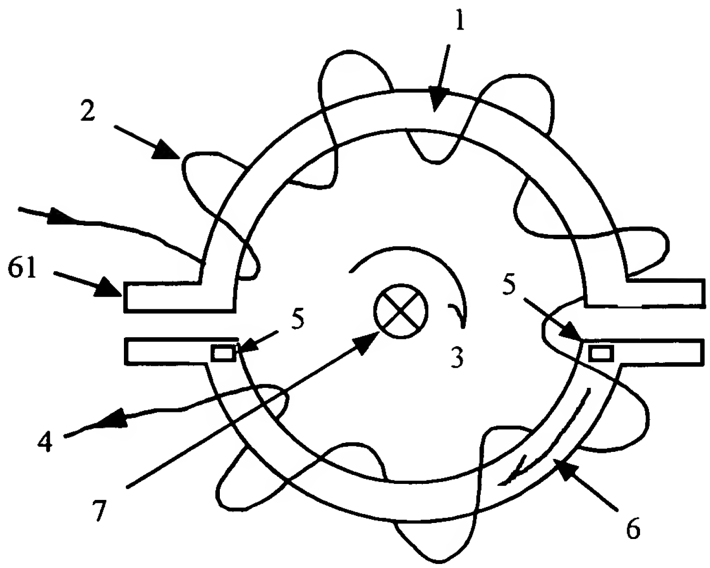

Fig. 1: A clamp-on sensor

The title for Fig. 3 says:

Fig. 3 illustrated interference from the non-uniform magnetic field H_n due to a magnet near the sensor.

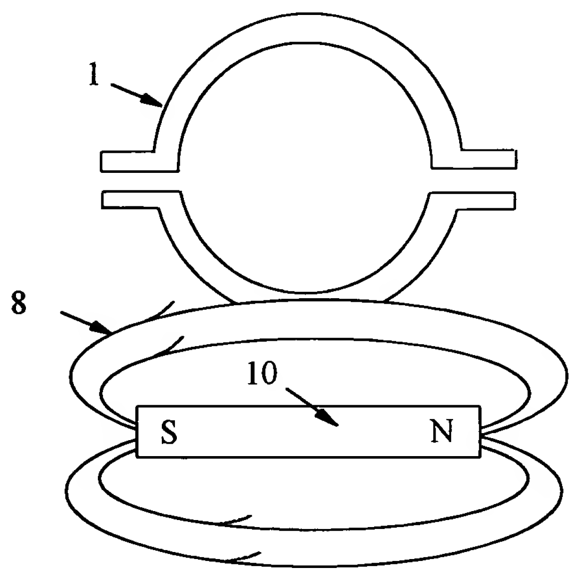

Fig. 3: A non-uniform magnetic field (H_n) 8 from a magnet acting on the core.

The signal and noise relationships are shown in illustrative example Fig. 4 and detailed on pages 11 to 13. Noise sensitivity Ψ" at point (A) is double that at point (B). Operating parameter I_{sm} is set at 0.4 A for low noise operating point B.

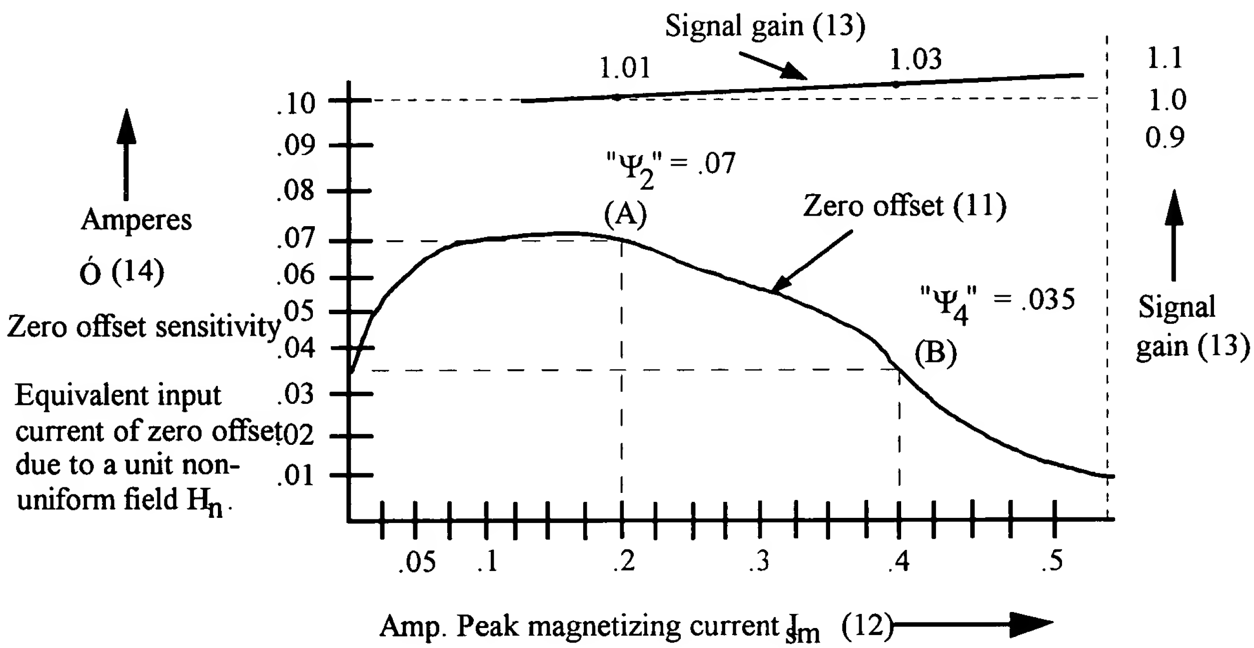

Fig. 4

Normalized "Signal Gain" "(g)" vs. I_{sm}
and
Normalized Zero Offset from H_n vs. I_{sm}
for
Five inch diameter aperture sensor #88.

Page 2 says:

Fig. 4 is a graph illustrating the "essential characteristic" discovered in a type of clamp used in some Swain Meters. As the operating parameter Ism increases, the signal gain increases only slightly, but the normalized output zero offset due to noise, here called Ó, first increases and then decreases to half and less.

11-2-98

"Means positioning" the "core" "so that it is influenced by a conductor carrying signal current I to be measured" are shown in Fig. 1. Input current I in conductor 7 sets up input magnetic field 3.

"Magnetic field noise N" is shown "within the effective range of the "core" in Fig. 3. The noise is H_n.

11-2-98

3.29 -75-

Claim 29 is for Swain Meter type sensor apparatus in species Better SNR.

The elements in claim 29 are described and the primary relationships stated on page 1, and also in the 21 Dec. 95 Abstract on page 52, thusly:

(a) Title: Error Correction by Selective Modulation

(c) Reference: U.S. Pat 3,768,011 granted to William H. Swain

(d) Summary.

This invention relates to sensors and/or implements for "measurement or control."

(h) Abstract of the Disclosure.

The "accuracy" of certain "sensors" is greatly improved by improving their signal to noise ratio (SNR) in the presence of an interfering noise. Sensors were discovered which have a SNR which substantially changes when an operating parameter is selectively modulated to different magnitudes. Some noise can be practically eliminated. In the simplest form, the sensor is operated where it is both stable and close to its best SNR. This is usually faster and less costly, but the noise is never completely eliminated.

The referenced patent Fig. 4, shows a core with winding similar to the 21 Dec. 95 application Fig. 1. "Input current I" flows in wire 13 which is "positioned" (in the aperture) to "influence" "core SQ". Other elements in Fig. 4 are specified in column 15:

11-3-98

-76-

pair of one of the sense inductors shown in FIGS. 4, 5 or 6 to the terminals designated V_S in FIG. 2.

Whenever practical, it is preferred to use a sense inductor core which has the torus or toroidal form of the magnetics 50057-½ F core shown for FIG. 2 because this generally reduces errors due to magnetic interference noise and circuit or core imperfections. The toroid core SQ with uniformly distributed winding N_S is the ideal design objective of the more convenient to use split core clip-on sense inductors L_S preferred when convenience in attaching the instrument is important.

A practical noise-cancalling "clip-on" DC ammeter "sensing" and "measuring" inductor which is used to resolve 1 milliampere direct current on a ± 50 ma full-scale instrument is shown in FIG. 4. Two half sections 1 and 2 of cylindrical tube having 0.5 inch outside diameter, 0.25 inch inside diameter, and 0.45 inches length, and made of relatively non-conducting and reasonably rigid material, such as plexiglass or Poly Vinyl chloride (PVC) are wound with one or more layers of "square loop" tape 3 and 4. Such a tape is found within the case of a toroidal "core" manufactured by Magnetics, Inc., of Butler. Pa., and designated 50094-1D. A single layer is preferred. The overlaps 5 and 6 are preferably ⅜ inch. The length of the cylindrical tube sections 1 and 2 is preferably a little more than the 0.4 width of the tape 3 and 4. The square loop tapes 3 and 4 may be held in place with insulating adhesive tape wound overall.

"SQ"

When the top and bottom halves are brought into intimate contact so as to minimize air gaps 7 and 8, there is formed a closed toroidal core such as is designated as "SQ" in FIGS. 1 and 2. The structure shown in FIG. 4 is especially designed to minimize the reluctance of the air gaps 7 and 8 even though there may be a small misalignment in joining halves 1 and 2. The large cross-sectional area at gaps 7 and 8 also reduces the flux density and thus reduces eddy current losses occurring where flux flows across the tape. However, the two halves of this toroid may be separated to admit one or more turns N_i of wire 13 carrying "input current" to be measured I_i without the need to disconnect one end of the wire and pass it through a closed toroid. This saves much time and labor in making measurements.

"SQ"

"I"

The two windings 9 and 10 each have 50 turns of 36 Anaconda HAN magnet wire. They are series-connected, so "N_S" = 100. The windings are made as uniform and symmetrical as feasible to optimize noise concellation. The total ohmic resistance R_S is about 5 ohms at lead wire pair ends 11 and 12. In use, these connect to terminals V_S in FIG. 2. The operating period T_0 is then 180 microseconds.

"N_S"

Ferrite or laminated steel "C" cores of UI cores of a variety of sizes may also be used to form core "SQ." Two essentially equal halves of Indiana General ferrite toroid core CF 106-06 having form similar to halves 1 and 2 in FIG. 4 are suitable for some purposes.

The core sections and windings 9 and 10 need not be symmetrical and balanced as shown in FIG. 4, bu this is preferred for noise cancellation as will be described.

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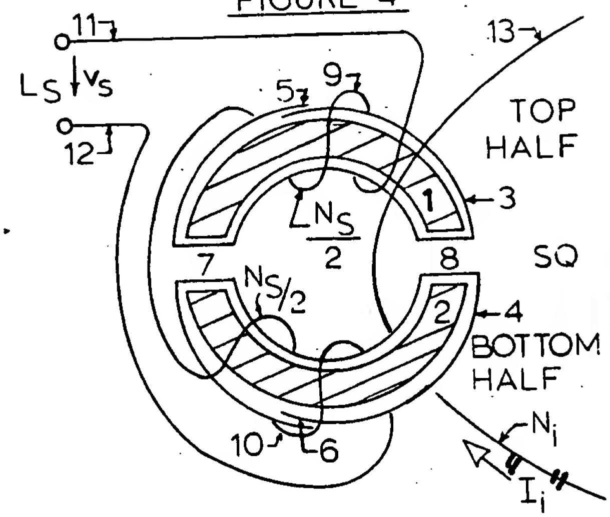
29

3.768.011

T 2 OF 3

FIGURE 4



Elements in claim 29 are interconnected in Fig. 1. "Inverter" "X" is included. Control input for operating parameter "I_{sm}" is shown at the top.

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3.768.011

SHEET 1 OF 3

FIGURE 1

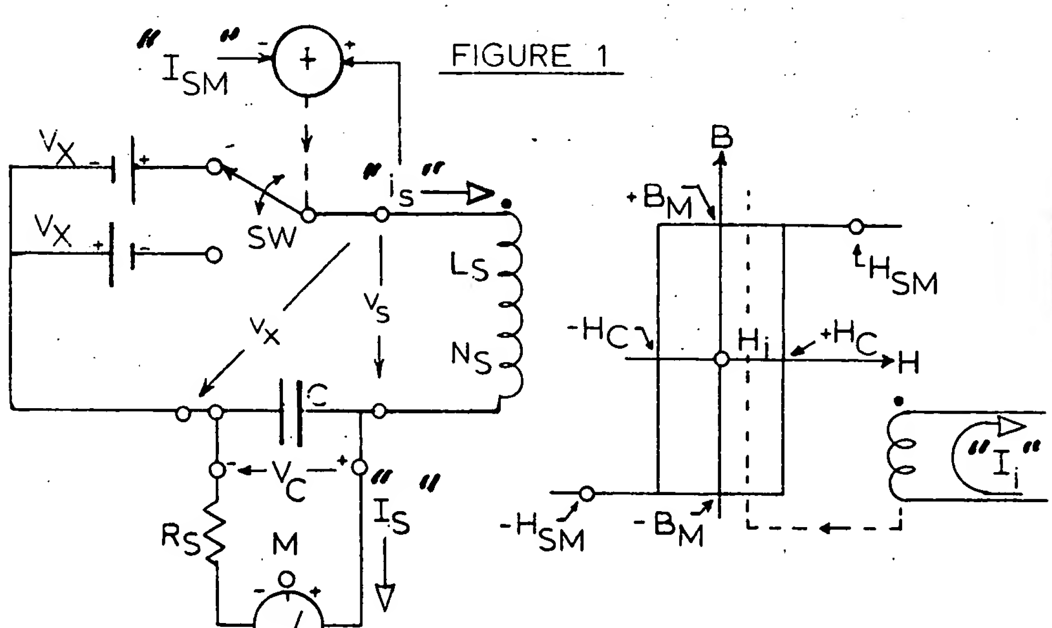

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Fig. 2 shows one means for "setting operating parameter I_{sm} to a greater magnitude." It is R_{sm} in series with battery V_{cc}.

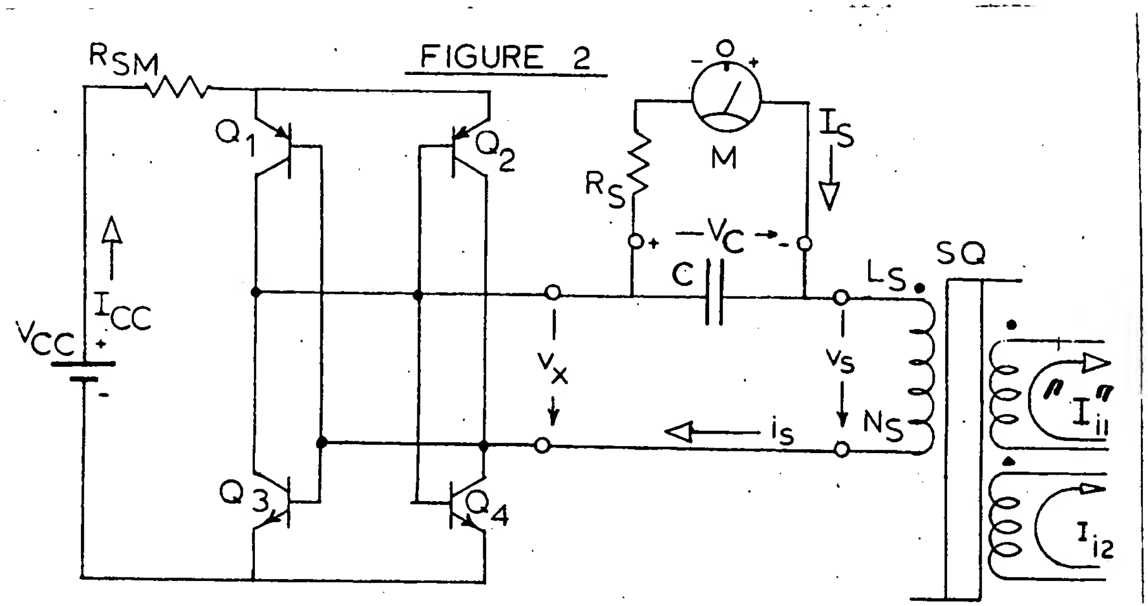

Fig. 3 of 21 Dec. 95 shows a core SQ "within the effective range of an interfering magnetic field noise" "N", called H_n. This causes a zero offset error which is minimized by operating at high SNR point (B) in Fig. 5. I_{sm} is set at 0.4 Amp to double the SNR, thus reducing error and thereby increasing "accuracy."

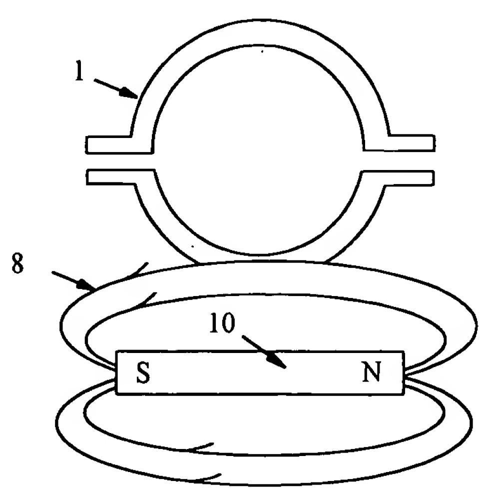

Fig. 3: A non-uniform magnetic field (H_n) 8 from a magnet acting on the core

-79-

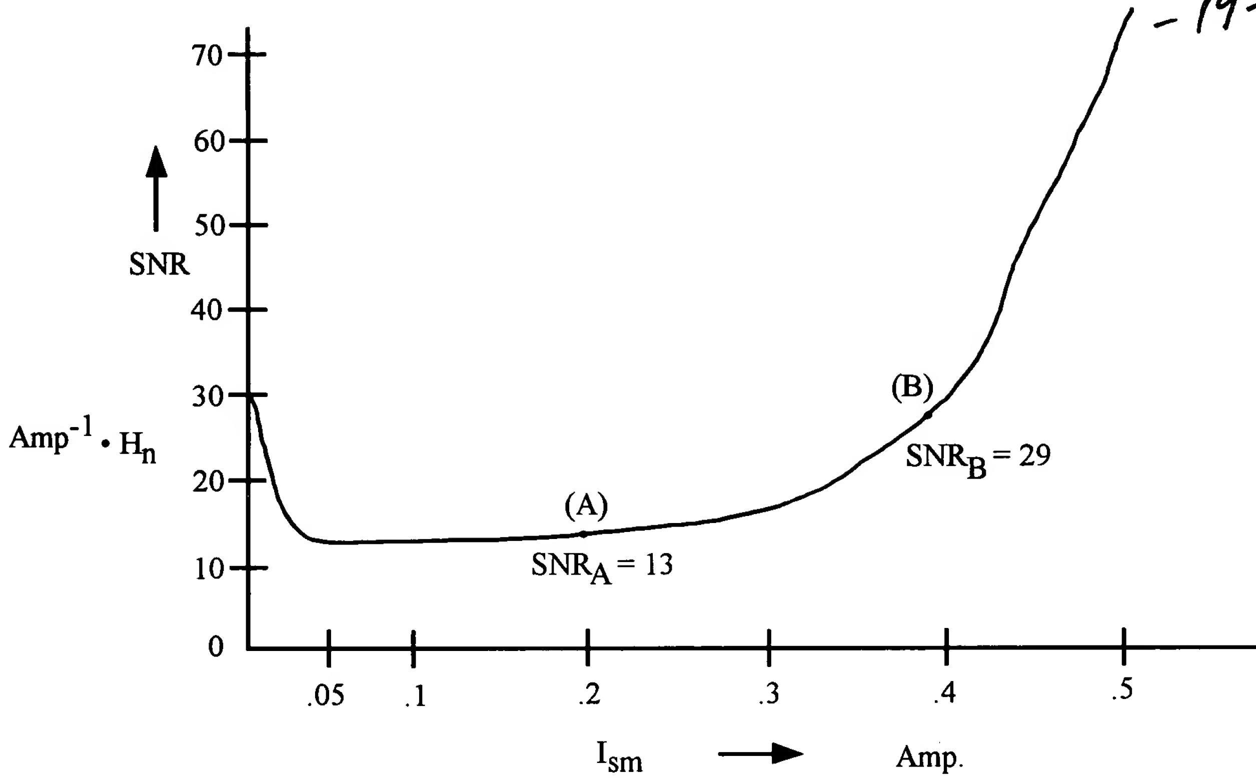

Figure 5
Signal to Noise Ratio (SNR) for Non-Uniform Field H_n
vs.
Operating Parameter I_{sm}

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-80-

6. Prior Art:

The examiner's cited prior art of Lucich teaches filter means to extract a mid frequency transducer signal from noise which has both a low frequency drift component and a high frequency "hash" component. Lucich's abstract says:

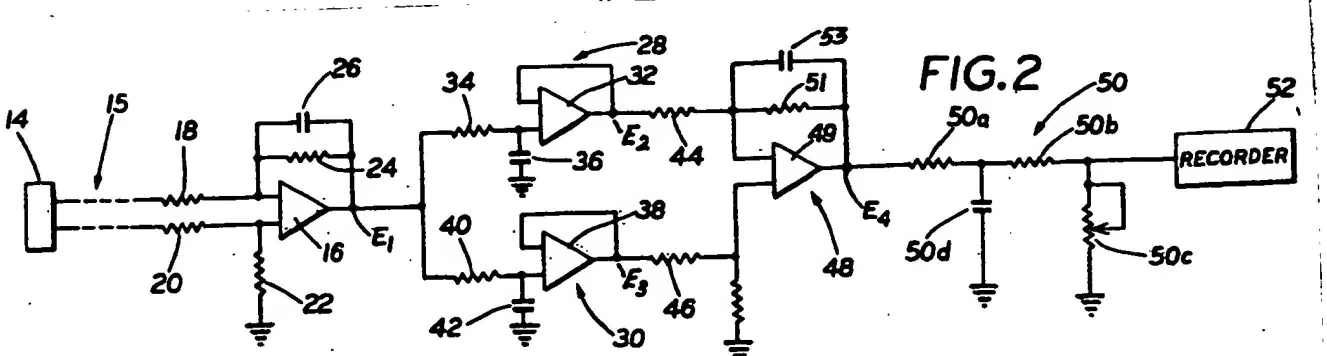
[57] **ABSTRACT**

In a transducer signal processing system wherein the output signal generated by a transducer (14) includes a nearly d.c., relatively large amplitude drift component (12), a higher frequency end point, data component (10) and a high frequency noise (hash) component (11), the drift and hash components are substantially eliminated by supplying the composite transducer output signal to a pair of parallel integrator circuits (28, 30) having different integration time constants. The faster integrator (28) passes the drift and data signal components, while attenuating the hash component, whereas the slower integrator (30) passes the drift component and attenuates the data and hash components. The output of the slower integrator (30) is subtracted from the output of the faster integrator (28) to provide a resultant signal containing essentially only the transducer data component.

The first line puts forth "... a transducer signal processing system..." The transducer is secondary to the claimed invention - a "signal processing system."

In extracting the signal, the transducer - typically a thermopile - is not changed by an operating parameter. It's signal to noise ratio (SNR) characteristic remains fixed. The signal is extracted with the aid of a pair of integrators with differing time constants. This is shown in his Fig. 2 and also his claim 1.

FIG.2



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PA 6.

Lucich Claims:

What is claimed is:

1. A circuit for reducing the d.c. outputted drift signal component from a transducer generated signal wherein the transducer signal includes the d.c. drift component to be reduced, a data component, and a high frequency noise component, said circuit comprising:
   first and second parallel integrator circuit means which receive and are responsive to said transducer signal;

Lucich claims a "...circuit..." with "...first and second parallel integrator..."

In contrast, applicant teaches a sensor having a SNR characteristic which changes a lot when an operating parameter changes. Applicant's 21 Dec. 95 Abstract says:

<u>(h) Abstract of the Disclosure.</u>

The accuracy of certain sensors is greatly improved by improving their signal to noise ratio (SNR) in the presence of an interfering noise. Sensors were discovered which have a SNR which substantially changes when an operating parameter is selectively modulated to different magnitudes.

Applicant's first line puts forth "...accuracy of certain sensors is greatly improved..." Applicants sensor is primary. The drawings start with a "clamp-on sensor." Page 2 says:

Fig. 1 is a functional diagram of a sensor with a split magnetic core SQ surrounding a conductor carrying a current I to be measured. The core will have a coupling sense winding N_S if it is to be used as a Swain Meter, or alternatively if it is to be used as a Hall type sensor, one or more Hall devices will replace the winding.

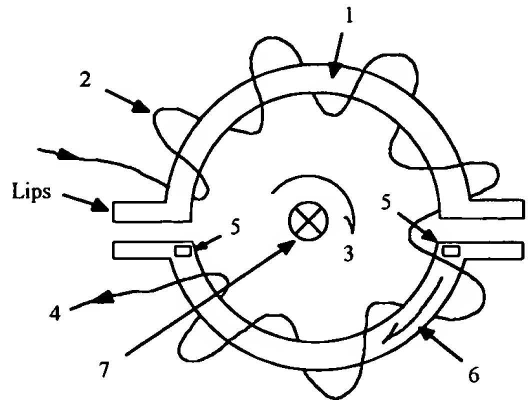

Fig. 1: A clamp-on sensor

Applicant also teaches "orthogonal modulation" for a Hall sensor in Fig. 12.

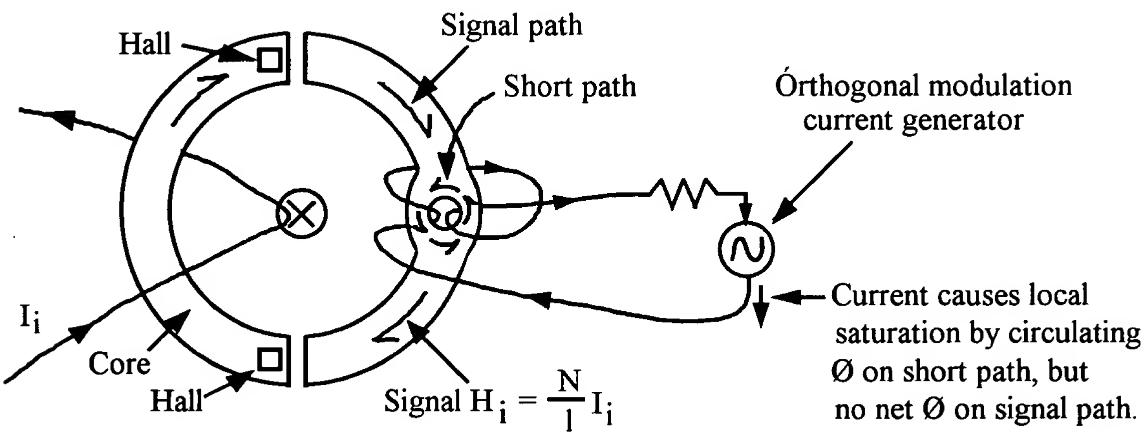

Fig. 12: Proposed core structure and magnetic reluctance selective modulation means for a Hall type clamp-on DC ammeter.

Moreover, applicant's 21 Dec. 95 claim 1 has the first step:

"find or construct a sensor with an output V which has a signal to noise ratio SNR which changes substantially when the condition of an operating parameter Q is selectively modulated."

Applicant is fundamentally different from Lucich. Applicant's start is a sensor - Swain meter clamp-on page 11:

11-3-98 PA 6

DISCOVERY

The inventor discovered that the output V of many Swain Meter clamps was a lot less sensitive (1/2 to 1/3 in some sensors) to a change in the intensity of a non-uniform magnetic field H_n when the magnitude of an operating parameter I_{sm} was doubled or tripled. And the sensitivity (gain) to a change in signal input current I stayed constant to within a few percent.

Applicant teaches a special kind of sensor, and process for making the sensor and implements, together with means for making the sensor - Swain, Hall, and other - useful. Lucich teaches a well known sensor (thermopile) with no mention that the sensor's signal to noise ratio is altered.

Applicant teaches a two (or more) state sensor having a different SNR in each state, due to a change in operating parameter. In contrast, Lucich (as well as Oswald and Meehan) teach transducers having only one SNR state.

In addition, applicant teaches removing noise at the same frequency as the signal. (DC).

In contrast, Lucich teaches removing noise at frequencies above and below the signal.

In the "combiner" species of the present invention, the subtract process is used - not to separate out a noise at a frequency different from the signal but to subtract one SNR state of the sensor from another to get out noise at the same frequency - DC - as the signal.

In the "combiner" species applicant teaches subtracting DC sensor output from a high SNR state from that at a low SNR state.

In contrast, Lucich teaches filters passing different frequency bands.

Lucich does not anticipate applicant.

11-3-98 PA 6

7. ; 8. ; 9.

Abstract

Sensors were discovered and later made which have the Essential Characteristic that they change from a high noise state to a low noise state when the magnitude of an Operating Parameter is selectively modulated - all while the Sensor's sensitivity to a signal holds relatively constant.

Put another way;

A particular sensor is said to have the Essential Characteristic if it's signal to noise ratio (SNR) changes a lot when the magnitude of an operating parameter is changed.

I use this discovery to make more accurate sensors of two types: noise canceling and better SNR. Noise cancellation results when the output of the sensor in a high noise state is divided and then subtracted from the output of the sensor in a low noise state. Division is adjusted so that the noises cancel. A good signal remains because the low noise and high noise signals were about equal before the high noise state was divided down.

In a simpler and faster form the sensor's operating parameter is set near maximum SNR, while maintaining stability. This form is also less costly and more effective in environments which differ greatly.

I have mostly built sensors of the Swain Meter type. I have also found one Hall type clamp-on ammeter which has the Essential Characteristic.

10-29-98

ABS.

-95-

Paragraph 10 Prior Art

10.1

Examiner's cited prior art of Oswald, Meehan and Lucich contains no teaching of applicant's generic claims #14, 30, and 31, in particular, and especially for the "Essential Characteristic." This is on specification Fig. 4, which is discussed on page 11. Nor do they make any statement which even hints at the "Discovery" which is also shown on page 11.

My annotated page 2 introduces Fig. 4:

Fig. 4 is a graph illustrating the "essential characteristic" discovered in a type of clamp used in some Swain Meters. As the operating parameter I_{sm} increases, the signal gain increases only slightly, but the normalized output zero offset (error) due to noise, here called Ó, first increases and then decreases to half and less.

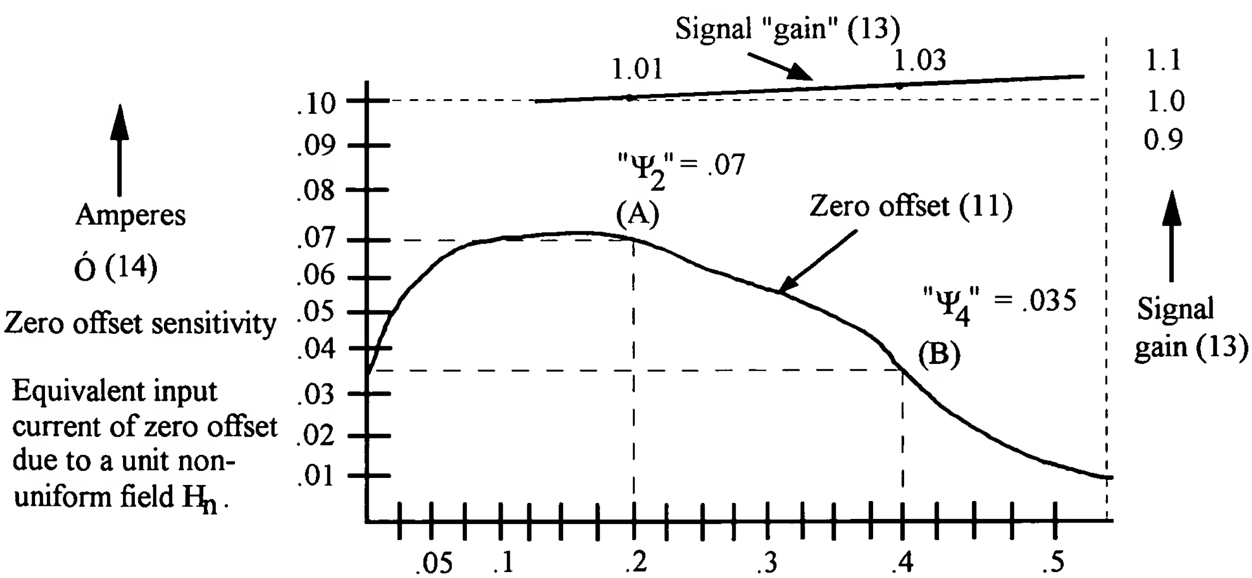

Fig. 4
Normalized Signal "Gain (g)" vs. I_{sm}
and
Normalized Zero Offset from H_n vs. I_{sm}
for
Five inch diameter aperture sensor #88.

11-3-98

PA 10.1

My annotated page 11 states:

"Essential Characteristic"

Fig. 4 shows the approximate sensitivities for a five inch diameter aperture clip #88. This is an illustration of a sensor having the "essential characteristic":

Firstly, the signal gain g (13) sensitivity to signal input I (7) is constant within a few percent as an operating parameter I_{sm} (12) changes from 0.18 A to 0.5 Amp peak; and

Secondly, the zero offset (error) (11) sensitivity to a unit change in intensity of a non-linear magnitude field H_n (8) is reduced to well under half over the same range of I_{sm} (12).

The "discovery" given on my page 11 led to the work shown in Fig. 4 above, and elsewhere.

DISCOVERY

The inventor discovered that the output V of many Swain Meter clamps (sensors) was a lot less sensitive (1/2 to 1/3 in some sensors) to a change in the intensity of a non-uniform magnetic field H_n when the magnitude of an operating parameter I_{sm} was doubled or tripled. And the sensitivity (gain) to a change in signal input current I stayed constant to within a few percent.

Put another way, Oswald, Meehan, and Lucich each, and all, lack a sensor having a big change in SNR when an operating parameter is changed.

The two to one change in SNR is illustrated in Fig. 8, with introduction from my page 3. Operating parameter Q is I_{sm} in a Swain Meter.

Fig. 8 is a graph illustrating a change in signal to noise ratio SNR vs. an operating parameter Q.

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PA 10.1

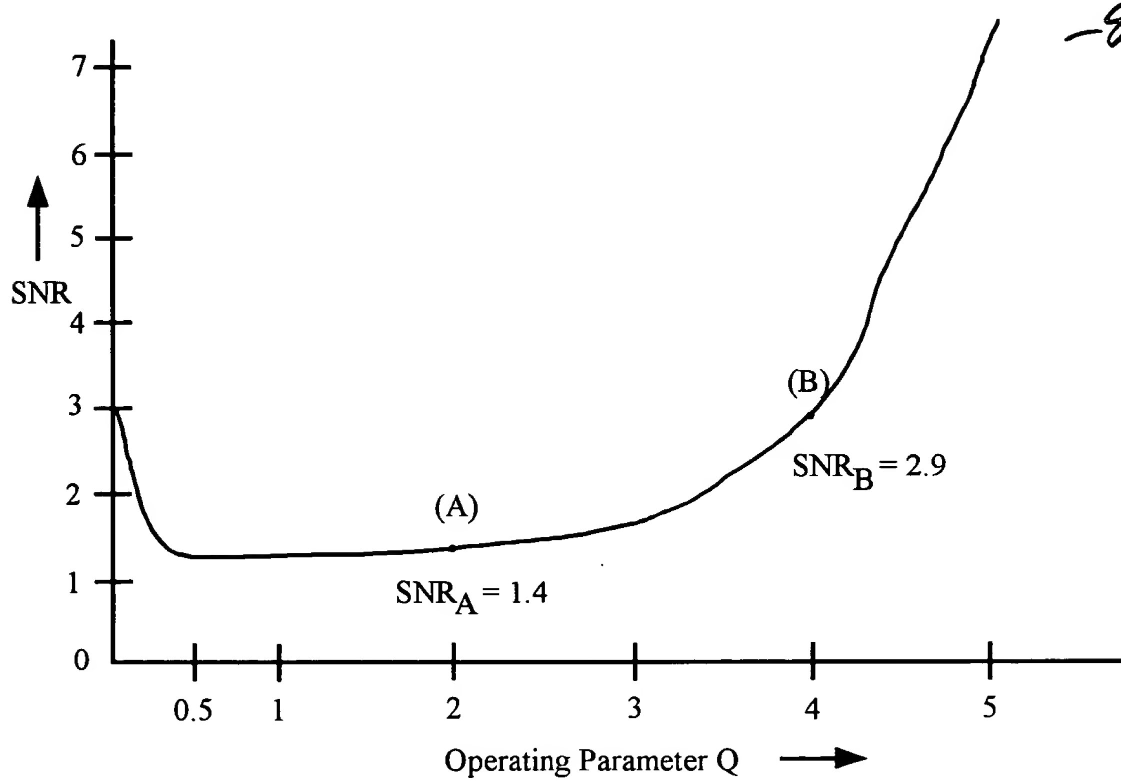


Figure 8
Signal to Noise Ratio (SNR)
vs.
Operating Parameter Q

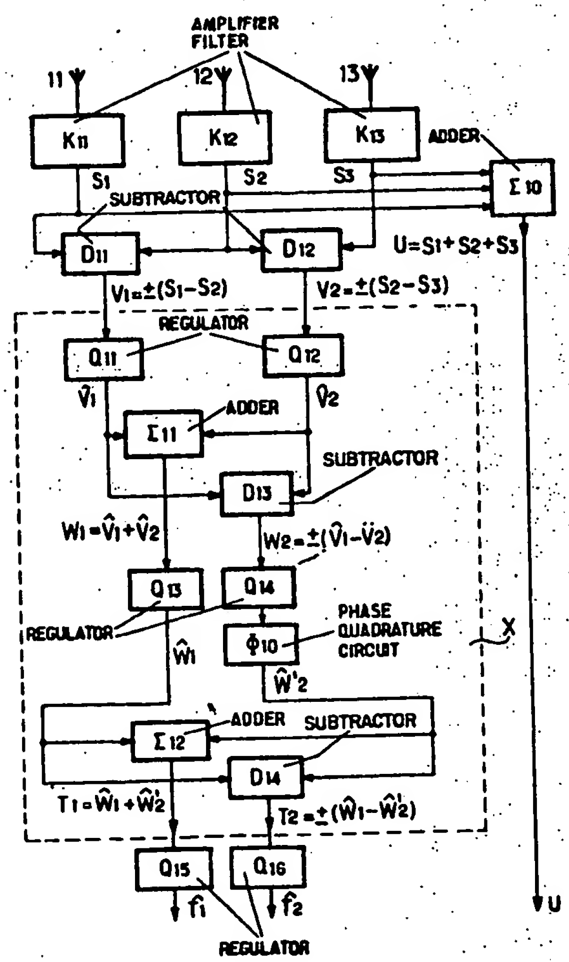
How to use this change in SNR to improve accuracy by reducing error in the sensors output when in the presence of an interfering noise source is summarized on page 1.

The method used is usually to find or construct a sensor which has a signal to noise ratio SNR which changes a lot when its operating parameter is selectively modulated. The output of the lower noise sensor is combined with the output of the higher noise sensor so that, in the ideal case, the noise cancels, but a good signal remains. The easier way may be to take part of the output of the higher noise sensor and subtract it from the output of the lower noise sensor. Two sensors can be used, or the operating parameter of one sensor can be modulated (driven) from a higher to lower noise state.

If there is one sensor, the operating cycle time is generally reduced to less than the time during which the signal and noise can be constrained to be constant. However, if two sensors or a combination are used, there is little need to keep signal and noise constant.

In contrast, Oswald never once - not in the specification, nor drawings, nor claims - mentions changing the SNR of a single transducer.

Oswald shows three (3) each transducers, or a minimum of two (2) in the cited co-pending application. These are also in the two drawings and one independent claim. Apparently one transducer will not do. I understand this, for likely he has a space diversity apparatus, and if the transducers are not separated, how can the noises differ so that they can be removed.



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United Stat
Oswald et al.

XS407T

[11] **3,784,915**
[45] **Jan. 8, 1974**

[57] **ABSTRACT**

Device for improving the signal/noise ratio of a common signal received on three aerials utilizing correlation between the sum and difference values of combinations of the signals from the three aerials to eliminate or substantially suppress the noise received with the common signal.

4 Claims, 3 Drawing Figures

11-3-98

PA 10.1

Applicant is basically different. He begins with, and carries all through the specification, drawings and all independent claims the generic single sensor having a SNR which changes a lot when an operating parameter changes.

Oswald does not anticipate applicant.

10.2

Meehan likewise has in his specification and drawings and claims a pair (two (2) each) or more detectors, arranged in what amounts to space diversity.

US005555530A

United States Patent [19] **Meehan**

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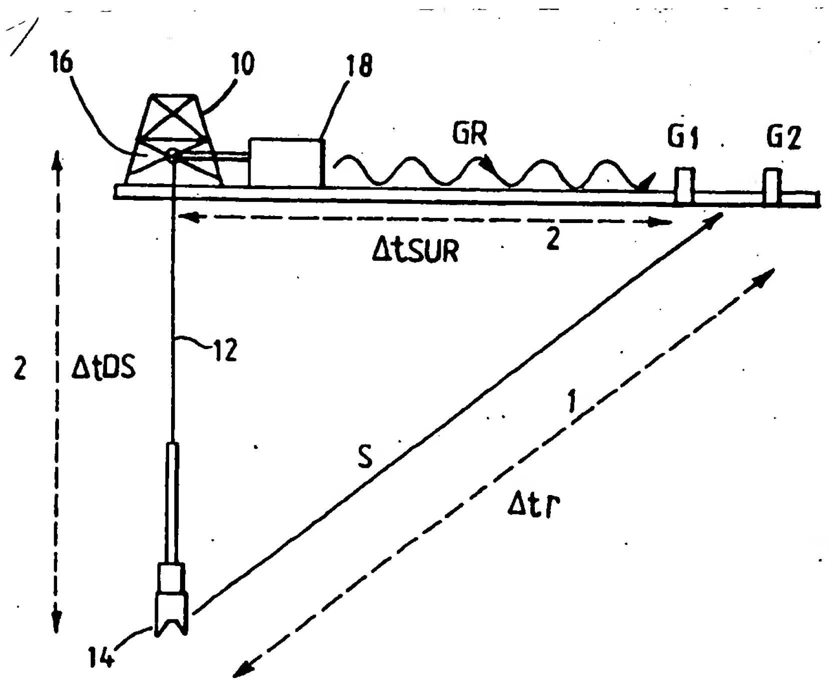

[57] **ABSTRACT**

A method for improving the signal to noise ratio from a pair of detectors such as geophones which each detect a noisy signal comprising a signal of interest (S) and a noise signal (N), wherein the signal of interest (S) has a different moveout across the pair of detectors from that of the noise signal (N), and the noise signal (N) from a given source is detected at the first detector at a time Δt before the corresponding noise signal is detected at the second detector, the method comprising delaying the noisy signal (S+N) detected at the first detector by an amount τ being greater than the moveout of the signal of interest but not more than Δt and subtracting the delayed signal from that detected at the second detector by means of an adaptive filter so as to minimize the power in the resultant signal. The signal detected at the first detection and optionally the resultant signal can also be delayed by an amount τ_2 and the signal detected at the second detector is subtracted from the delayed first detector (and resultant signals) by means f an adaptive filter so as to minimize the power in the final signal, the delay τ_2 being greater than the moveout of the signal of interest plus the length of the filter but not more than Δt plus the length of the filter.

26 Claims, 11 Drawing Sheets

11-3-98

PA 10.2

In contrast applicant teaches a single sensor throughout most of his specification, drawings, and all independent claims. A compound sensor or pair of sensors, likely close together, are described if the need for speed obviates storage of data.

Moreover, Meehan never once - not in the specification, nor drawings, nor claims - mentions changing the SNR of a single transducer.

In contrast, applicant begins with, and carries all through the specification, drawings and all independent claims the generic single sensor having a SNR which changes a lot when an operating parameter changes.

Meehan does not anticipate applicant.

10.3

Lucich, in the examiner's cited prior art, is traversed in detail in preceding paragraph 6. I here note:

Lucich teaches filter means to extract a mid frequency transducer signal from noise which has both a low frequency drift component and a high frequency "hash" component.

Swain is basically different. He teaches removing noise at the same frequency as the signal (DC).

Lucich (as well as Oswald and Meehan) teach transducers having only one SNR state. In contrast, applicant teaches a sensor having a SNR characteristic which changes a lot when an operating parameter changes.

Lucich does not anticipate applicant.

11-3-98 PA 10.3